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CRITICAL DEPTH TESTS OF COMPOSITION B FLAKE.(U)

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AMMANN AND WHITNEY, NEW YORK

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CRITICAL DEPTH TESTS OF COMPOSITION B FLAKE

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This report covers description and results of 75 tests conducted to devise means of safely conveying Composition B Flake between Automatic Inspection Building (E-125) and Melt/Pour Buildings (E-120 and E-123) under a program to modernize the 105 mm LAP line at Lone Star AAP, Texarkana, Texas. Variable factors such as depth of explosive on the conveyor, width of conveyor, separation between two adjacent batches of explosives and other means of achieving this separation were considered in these tests. It was found that commercially available 0.38 m (15 in.) wide rubber belt conveyor with corrugations can be used to prevent

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propagation of explosion from one end of the conveyor to the other, if the explosive was restricted only to the trough area and the minimum clear distance between the explosives in two adjacent troughs was maintained at 51 mm (2 in.).

Appendix A to this report describes the preliminary burning and propagation of detonation tests of TNT, Composition B, Tritonal and H-6 by the U.S. Navy, whereas Appendix B provides statistical evaluation of explosion propagation .

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ABSTRACT

Seventy-five tests were conducted to devise means of safely conveying Composition B Flake between Automatic Inspection Building (E-125) and Melt/Pour Buildings (E-120 and E-123) under a program to modernize the 105 mm LAP line at Lone Star AAP, Texarkana, Texas. Variable factors such as depth of explosive on the conveyor, width of conveyor, separation between two adjacent batches of explosives and other means of achieving this separation were considered in these tests. It was found that commercially available 0.38 m (15 in.) wide rubber belt conveyor with corrugations can be used to prevent propagation of explosion from one end of the conveyor to the other, if the explosive was restricted only to the trough area and the minimum clear distance between the explosives in two adjacent troughs was maintained at 51 mm (2 in.).

Appendix A to this report describes the preliminary burning and propagation of detonation tests of TNT, Composition B, Tritonal and H-6 by the U. S. Navy, whereas Appendix B provides statistical evaluation of explosion propagation.

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SUMMARY

Tests described in this report cover one phase of an overall safety engineering program entitled "Safety Engineering in Support of Ammunition Plants" conducted under the guidance of the Manufacturing Technology Directorate, Picatinny Arsenal, Dover, New Jersey, for the U. S. Army Armament Command (ARMCOM).

The tests were performed to determine ways of safely conveying Composition B Flake between Automatic Inspection Building (E-125) and Melt/Pour Buildings (E-120 and E-123) at Lone Star AAP. They were divided into four series as described below.

The first series of 16 tests was performed using commercially available rubber belt conveyor and simulated conveyors, fabricated from wood. The conveyors were supported on wooden ammunition boxes and covered with aluminum covers. The lengths of conveyors used were 1.52 m (5 ft.), 2.44 m (8 ft.), 3.05 m (10 ft.), and 4.88 m (16 ft.). The depth of Composition B Flake was varied from 25 mm (1 in.) to 50 mm (2 in.) in the increments of 6.35 mm (1/4 in.). Two widths of the conveyor used were 0.29 m (11-1/4 in.) and 0.44 m (17-1/2 in.). Each test was initiated at one end of the conveyor using Composition C4 booster. It was observed from the detonated length of the conveyors and the size of the craters at the test site that 0.29 m (11-1/4 in.) conveyor was more suitable from the safety standpoint than the 0.44 m (17-1/2 in.) wide conveyor for the same depth of explosive.

The second series consisted of 18 tests and used 0.29 m (11-1/4 in.) and 0.43 m (17 in.) wide simulated wooden conveyors. 76 mm (3 in.) high by 6.3 mm (1/4 in.) thick rubber cleats were glued or stapled into the wooden conveyors at various spacings. These cleats are necessary to hold the explosive in its place when conveyed on an incline. In the initial tests of this series the explosive was placed on the conveyor and divided into a number of segments using a different number of cleats in each test. High order detonation propagations in two tests made it clear that the cleats cannot be relied upon for prevention of propagation of explosions. This resulted in the air-gap concept where air-space was used to separate two adjoining batches of Composition B Flake each weighing approximately 25 kg (55 lbs.). All tests, with air-gaps ranging from 0.075 m (3 in.) to 0.61 m (24 in.), were successful.

Having seen the usefulness of the air-gap concept, the third series of tests was directed at finding practical means to use this concept for conveyors. Two different kinds of spacers, one

round and one square, were devised and tested in 21 tests. Seven of these tests used rubber belt conveyors and the rest used simulated wooden conveyors. All tests proved successful using a 0.1 m (4 in.) air-gap.

The fourth and the last series of 20 tests was confirmatory in nature and was performed using commecially available corrugated rubber belt conveyors. The clear separation between the explosives in two adjacent troughs of the conveyor was maintained at 51 mm (2 in.) by the undulations of the conveyor. Some tests used the two-acceptor arrangement while one-acceptor was used in the remaining tests. There was no detonation propagation in any one of the 32 acceptors employed. This corresponds to reliabilities for the non-occurrence of propagation of 0.91, 0.89, and 0.85 for 90, 95, and 99 percent confidence limits, respectively. If all tests with 0.1 m (4 in.) separation or less and depth of explosive of 38 mm (1-1/2 in.) or more are considered, then the reliabilities increase to 0.96, 0.95, and 0.92 for 90, 95 and 99 percent confidence limits, respectively.

Preliminary burning and detonation propagation tests performed by the Navy on TNT, Composition B, Tritonal, and H-6 are described and their results summarized in Appendix A. Maximum probabilities of propagation for given confidence limits are discussed in Appendix B.

SECTION 1

INTRODUCTION

1.1 Background

At the present time, an army-wide expansion program is underway to upgrade the existing, and to develop new explosive manufacturing and LAP (Load-Assemble-Pack) facilities. Increase in the production cost-effectiveness and improvement in safety records are expected from this effort. As a part of the overall program, the Manufacturing Technology Directorate of Picatinny Arsenal, Dover, New Jersey, under the direction of the U. S. Army Armament Command (ARMCOM) is engaged in developing safety criteria. The program is labelled as "Safety Engineering in Support of Ammunition Plants", and the criteria developed will be used as the basis for the design of all future explosive production installations.

Table 17-1 of the Safety Manual (Army Materiel Command Regulation AMCR 385-100) lists the safe spacings of ammunitions and explosives in boxes. However, there is no information for loose Composition B Flake on conveyors. Therefore, the tests described in this report were undertaken to devise means of safely conveying Composition B Flake on conveyors between Automatic Inspection Building (E-125) and Melt/Pour Buildings (E-120 and E-123) of the 105 mm LAP line at Lone Star Army Ammunition Plant, Texarkana, Texas. This information is also applicable to other similar LAP facilities.

Earlier in 1972, the U.S. Navy had performed some burning and propagation of detonation tests on different explosives. These tests are briefly summarized in Appendix A.

1.2 Objective of Test Program

The primary objective of this test program was to develop means to prevent accidental propagation of detonation from one part of the conveyor carrying loose Composition B Flake to the other by devising simple and economical modifications to the commercially available conventional conveyor systems. The secondary objectives were:

(1) To determine effects on propagation produced by the variation of the depth and width of the explosive on the conveyor; and

(2) To determine whether the material of construction of the conveyor had an effect on detonation propagation.

1.3 Criteria for Confirmatory Tests

Initially it was intended to perform 50 confirmatory tests with one donor and one acceptor, or 25 confirmatory tests with one donor and two acceptors, after the safe depth of Composition B Flake had been determined from the previous tests. These 50 observations with no propagation of explosion in any one observation conform to lower limits of probabilities of no propagation of 93 and 90 percent, for confidence levels of 95 and 99 percent, respectively. The upper limit would be 100 percent no propagation of explosion for all confidence levels.

After three series of tests were completed, 38 mm (1-1/2 in.) was selected as a safe depth of explosive on a 0.38 m (15 in.) wide conveyor. Nineteen tests, some with double acceptors giving a total of 32 observations, were performed without any propagation of explosion in the fourth series of tests. Due to a time factor and desire to reduce the testing costs, an approval from DARCOM and ARMCOM Safety to conclude the test program at this point was sought and granted.

These 32 observations provide an 85 percent reliability for a 99 percent confidence level as explained in Appendix B.

SECTION 2

DESCRIPTION OF TEST SETUPS

2.1 General

The test program was initiated in November of 1974 to determine the critical depth of Composition B Flake on conveyors connecting the Automatic Inspection Building and the Melt/Pour Buildings of the 105 MM LAP Line at Lone Star AAP. The critical depth is defined here as the depth of explosive bed on the conveyor which is safe, i.e., which will not aid in spreading a detonation from one end of the conveyor to the other; and at the same time is compatible with the production rate of the plant in that it allows the flow of Composition B Flake in a continuous fashion without interrupting the process. It was realized from the beginning that because of this dual requirement, some form of modification to the commercially available conveyors would be necessary to make them both safe and operable.

The test program was broken into four parts or four series. In the first series of tests, the depth of explosive as well as the width, length and type of conveyor were varied for different tests. In the second series empty spaces and/or rubber cleats used as interrupters were investigated in addition to the variations of bed depth and conveyor dimensions. In the third series, the critical depth with an air-gap was established; and confirmatory tests were performed on this depth of explosive in the last series. The setups and results of the tests performed in these four series are described below.

2.2 Test Series No. 1

This series consisted of 16 tests. In order to simulate the actual plant conditions, all tests used covered conveyors. The covers simulated confinement produced by the dust collection system. The round covers were available at Tooele Army Depot from a previous test program and were modified for use in this test program. Each cover was 0.61 m (2 ft.) wide by 0.91 m (3 ft.) high and made from aluminum sheets.

The conveyor proper was simulated by supporting either rubber or wooden troughs on empty ammunition boxes at a height above the ground of about 0.33 m (13 in.). The actual plant height would have been difficult to simulate since it varies greatly. Two different conveyor widths, 0.29 m (11-1/4 in.) and 0.44 m (17-1/2 in.), and four different lengths, varying from 1.52 m (5 ft.) to 4.88 m (16 ft.) were used. A typical

test setup is shown in Figure 1.

Composition B Flake was levelled at various accurately measured depths within the conveyor. This accuracy was accomplished by means of a fabricated jig. The depth of the flake varied from 25 mm (1 in.) to 50 mm (2 in.) in the increment of 6.25 mm (1/4 in.). Initiation of the explosive was performed with the use of a 25 mm (1 in.) thick Composition C4 booster and a No. 8 blasting cap. Except for four tests, the height and length of each booster was the same as that of the explosive. In those four tests the depth of the booster was adjusted to be higher than the depth of the explosive. Fuse wire was inserted into the Composition C4 and attached to the blasting cap. This was manually initiated by a fuse lighter. The experiments were observed from a bunker approximately 800 m (1/2 mile) away. The Composition B used in the tests was Grade A bulk flake, and having Holston AAP lot numbers HOL. 053-5385 and HOL. 053-138 dated June 1974 and November 1974, respectively.

All tests resulted in high order detonations, forming craters under the conveyors. Summary of the test setup and results for Series No. 1 is presented in Table 1.

2.3 Test Series No. 2

Eighteen tests (Test Nos. 17 to 34) were conducted in connection with this test series. Except for Test No. 19, where the enclosure was omitted, the test setup of this series is shown in Figure 2. All enclosures with flat roofs were fabricated at Tooele Army Depot from 1.6 mm (o.063 in.) thick aluminum sheeting and supported by 1-1/2 in x 1-1/2 in x 1/8 in. structural steel angles. All enclosures were 0.61 m (2 ft.) wide and 0.91 m (3 ft.) high and 2.44 m (8 ft.) long. All simulated conveyors were made from wood; and the booster and method of initiation were the same as that of the Test Series No. 1.

Due to high order detonations in Series No. 1 when the flake was continuous, interrupters were used in this series of tests. One test setup consisted of rubber pads, 76 mm (3 in.) high by 6.3 mm (1/4 in.) thick and having a width equal to that of the conveyor, either glued or stapled into the conveyor at various spacings. These pads or cleats would be required to hold the explosive in place when conveyed on an incline in the plant. In the second test setup, a pair of rubber cleats was used to form an empty space between two batches of explosive. By changing the spacing between the cleats, the air-gap between the adjacent batches of explosive was varied. This arrangement is referred to as the air-gap system. Thus one, two, or three air-gaps were provided on the conveyor. The lengths of air-gaps

tried were 0.076 m (3 in.), 0.15 m (6 in.), 0.30 m (12 in.) and 0.61 m (24 in.).

When used in combination with the air-gaps, the cleats were found to be effective in eliminating propagation. However, when used by themselves, the cleats were ineffective. Test setups and results are summarized in Table 2.

2.4 Test Series No. 3

Twenty-one tests (Test Nos. 35 to 55) of this series were a continuation of the second series where it was observed that the air-gaps were effective in prevention of detonation propagation. Since a continuous feed to the conveyor was considered to be the most practical approach, various air-gap or separation techniques were investigated, of which two were selected for feasibility testing. The two designs, a square and a round, utilized a 0.1 m (4 in.) air-gap as shown in Figures 3 and 4 respectively. The square box-like design consisted of two 38 mm (1-1/2 in.) high rubber cleats spaced 0.1 m (4 in.) apart with 3.2 mm (1/8 in.) thick rubber sheet glued to the top of the cleats. The round design consisted of a 1.6 mm (1/16 in.) steel plate bent to a 0.13 m (5 in.) radius with a 3.2 mm (1/8 in.) thick rubber sheet glued to the top of the steel plate. When the Composition B Flake was poured and levelled in the conveyor to a depth of 38 mm (1-1/2 in.), this convex shape provided approximately a 0.1 m (4 in.) separation on the top of the spacer between the two adjacent Composition B batches. These designs referred to as spacers were either glued or stapled into the test conveyors.

Three tests of this series used commercially available rubber belt conveyors, but the remaining 18 tests were performed using wooden conveyors. In all tests the conveyors were supported by empty metal ammunition boxes at a height of 0.38 m (15 in.) above the ground. Figures 5 and 6 illustrate the test setups for square and round spacers, respectively, without the enclosures. In three tests a small amount of Composition B dust was added to the top of the air-gap covers to create a more hazardous condition. The Composition B dust did not help in detonation propagation. It may be noted that in more than half of these tests, the point of initiation was located at the center of the conveyor. This arrangement permitted the use of two acceptor sections, one located at each end of the simulated conveyor. Table 3 summarizes the results of Test Series No. 3.

2.5 Test Series No. 4

Previous exploratory tests of Series 1 through 3 proved

that a continuous bed of Composition B could not be safely conveyed without the risk of the occurrence of detonation propagation. Various techniques utilizing air spaces between batches of Composition B tested on simulated wood conveyors and commercially available rubber belt conveyors were successful in precluding propagation of explosion. Various available conveyors were investigated to check their suitability for providing air-gap cleats. One rubber belt conveyor with corrugations was chosen for testing since the explosives in two adjacent troughs could be separated by 51 mm (2 in.) when the depth of the explosive in the troughs would be less than the depth of the corrugations. For this series, the conveyor was supported on ammunition boxes at a height of 0.76 m (30 in.) from the ground.

Of the 20 tests performed in this test series, 19 were confirmatory and used 38 mm (1-1/2 in.) depth of explosive on 0.39 m (15 in.) wide conveyors. The only nonconfirmatory test had a 51 mm (2 in.) depth of explosive on a 0.43 m (17 in.) wide conveyor. In six of the 19 tests the Composition C4 booster was positioned at one end of the conveyor; while in the remaining tests the booster was placed in the middle, and the acceptor explosive was located on either side of the booster. Figures 7 and 8 illustrate the test setup for this series of tests. Although the damage shown in Figure 9 seems more extensive, it is mainly due to the collapse of the ammunition boxes as a result of the blast wave. Summary of this test series is given in Table 4.

SECTION 3

ANALYSIS OF TEST RESULTS

3.1 General

Results of individual tests are presented in Tables 1 through 4. To facilitate comparison and analysis, tests with identical test setups are grouped together. In most cases few tests were conducted for each depth of explosive bed, width of conveyor, and air-gap; so only qualitative statements can be made about their results. However, for a 38 mm (1-1/2 in.) depth of explosive and a 0.1 m (4 in.) air-gap separation, the number of observations were significant to merit a quantitative evaluation for predicting the probability of explosion propagation with a certain degree of confidence.

It should be noted that the various tests were performed using the simplest conveyor arrangement, i.e., straight conveyor at constant height above the ground. No account was taken of conditions such as conveyor curvature, inclination of conveyor, or adjoining conveyor carrying explosives. Nevertheless, it is believed that the results as achieved would not have been different even with the test setups simulating the more complicated conveyor layouts of actual plant operations.

3.2 Explosive Distributed along the Entire Conveyor Length with Booster at One End

Eighteen tests were conducted using this kind of test setup in Series 1 and 2. Commercially available rubber belt conveyor and simulated wooden conveyor were used in seven and eleven tests, respectively. All 18 tests resulted in transmitting explosion from the booster end to the other end of the conveyor. Breakdown of these tests according to the materiel of construction, length and width of the conveyor, and depth of the explosive as well as the test results are shown in Figure 10.

The depth of explosive and the width of conveyor are interrelated for given production rate and conveyor speed, i.e., the bigger the width of the conveyor, the smaller will be the depth of explosive required. Therefore, the depths were varied to see what was the maximum depth of explosive that could be carried by a given width of conveyor without detonation propagation. Because of practical considerations the maximum width was limited to 0.45 m (18 in.) and the minimum depth to 32 mm (1-1/4 in).

Several general observations can be made from this test setup based on the intensities of detonations and the dimensions of craters formed in the ground at the test site. For a given depth of explosive and length of conveyor, a wider conveyor would produce a more severe detonation and hence more severe damage. Another self-evident result is that the intensity of explosion is proportional to the depth of explosive. For smaller depths, the detonation propagation travelled only a fraction of the conveyor length and then subsided, whereas for greater depths the entire conveyor was engulfed in an all-consuming fireball. As may be expected, larger craters were also formed with the bigger depths of explosive.

As for the material of conveyor construction, there is no evidence to suggest that it affected the outcome of the tests. Simulated wooden conveyors were used for economical reasons. They were easy to form and readily usable. For commercially available rubber belt conveyors, the procurement procedures and delivery schedules would have produced a cost impact and caused a considerable delay in the test schedule. Since no difference was observed in the test results, it became relatively easy and cheaper to perform all remaining tests using the wooden rather than the rubber conveyor arrangement.

Since propagation of explosion took place in all 18 tests, it can be said that this mode of conveying explosive on conveyors is definitely not suitable from the safety standpoint.

3.3 Explosive Distributed over Conveyor Length with Intermediate Cleats

Four tests were performed in Test Series No. 2 using rubber cleats. It was anticipated that the cleats would prevent detonation propagations, but it turned out that in all four tests the explosion from the booster propagated the full length of the conveyor. Figure 11 illustrates the breakdown of this test setup as well as the results of individual tests.

Cleats were deemed necessary on the conveyor to hold the explosive in place. However, the cleats as used in these tests were too narrow to provide safe separation between adjacent batches of explosive. Thus, this test setup was just like the one above which was found to be ineffective in preventing explosion propagation.

3.4 Conveyor with Donor and Acceptor Separated by Air-Gap

Wooden conveyors were used to perform these 16 tests. Air-gaps ranging from 0.076 m (3 in.) to 0.61 m (24 in.) were utilized successfully in preventing propagation of explosions for depths of explosive varying from 38 mm (1-1/2 in.) to 70 mm (2-3/4 in.). Breakdown of these tests and their results is shown in Figure 12.

This was the first group of tests where the concept of air-gap was fully applied. The air-gap was formed by a pair of cleats which in turn separated the two batches of explosive. Three different lengths and two different widths of conveyor were used. The depths of explosive ranged from a low of 38 mm (1-1/2 in.) to a high of 70 mm (2-3/4 in.). Explosion of the donor had no effect on the acceptor across the air-gap as small as 76 mm (3 in.). This led to the use of 0.1 m (4 in.) wide square and round spacers which were proved to be feasible for actual use and successful in later testing.

3.5 Conveyor with Two Air-Gaps

In this test setup the explosive was divided into three batches with 0.30 m (12 in.) air-gap separating the adjoining batches. The booster located at one end of the conveyor could not transmit the explosion across the gaps to the other two batches of explosive. Figure 13 provides the details of this test setup. Only two tests were performed using this test set-up, but their results proved the effectiveness of the air-gap concept.

3.6 Conveyor with Three Air-Gaps

Only one test was performed with this test setup where four batches of explosive were separated by three air-gaps each 0.30 m (12 in.) wide. There was no propagation of explosion from the donor batch located at one end of the conveyor to the other three acceptor batches. Details of this test setup are shown in Figure 14.

3.7 Conveyor with Donor in the Middle and Acceptors on Ends

Fourteen tests using rubber and wooden conveyors were performed where the booster was placed in the middle of the donor explosive and the two acceptor batches of explosive were separated from the donor by 0.1 m (4 in.) wide square and round spacers. This arrangement provided two observations for each test performed. Figure 15 shows the breakdown of different variables of this test setup as well as the test results. As

can be seen, propagation of explosion did not occur in any test.

This was the first test setup where two independent observations were provided in each test by locating the donor in the center of the conveyor and by positioning one acceptor on each side of the donor. Eleven tests using wooden conveyors and three tests using rubber conveyors provided 22 and 6 observations, respectively, with no propagations.

In the case of wooden conveyors there was no detonation propagation in 22 observations. Hence, the observed probability of propagation (p) was zero. Had additional tests been performed, the probability of propagation would not have been exactly zero but between zero and an upper limit p_2. This upper limit p_2 depends not only on the number of observations, but also the confidence limit (C.L.), a number expressed as a percent - such as 95 percent or 99 percent. Numerical values of the upper limits of probability p_2 are tabulated in Appendix B and plotted in Figure 16. Thus we see that for 22 observations the values of probability of propagation are 13 percent for 90 percent C.L., 15 percent for 95 percent C.L., and 21 percent for 99 percent C.L.

3.8 Corrugated Conveyor with Booster at One End

Corrugations provided 51 mm (2 in.) air-gap between the explosives in two adjacent troughs of a commercially available corrugated belt conveyor. Seven tests were performed using this test setup where the booster was placed in the trough at one end of the conveyor. The depth of explosive in 6 tests was 38 mm (1-1/2 in.), whereas in the seventh test it was 51 mm (2 in.). Propagation of explosion occurred in the seventh test where the 51 mm depth of explosive exceeded the 38 mm depth of the conveyor corrugations, and thereby provided a direct path for explosion propagation along the conveyor. Parameters of this test setup are shown in Figure 17.

In a true sense this arrangement was single donor with multiple acceptors; and was used to determine if firebrands produced from the detonation of the donor batch, or hot fragments generated from the breakup of the conveyor cover would ignite an acceptor batch further down the conveyor. For statistical analysis only the explosive in the first trough adjacent to the donor trough was considered since it had a separation of 51 mm (2 in.). Explosive in each successive trough acted as an independent acceptor with its own separation distance from the donor. Thus the explosive in the second trough could only be considered for statistical analysis if the explosive in the first trough

propagated, and so on.

These 6 successful tests provided 6 observations which have been combined with observations obtained from the next test setup described below for statistical analysis.

3.9 Corrugated Conveyor with Donor in the Middle

In this case the booster was placed in the middle trough of the corrugated conveyor; and the explosive in troughs of each side of the booster trough acted as acceptors. In all 13 tests performed using this test setup, there was no detonation propagation. Details and results of this test setup are shown in Figure 18.

This test arrangement provided two acceptors for each test with a separation of 51 mm (2 in.) from the donor. There were 26 successful observations in this test setup. Combining 6 observations from the test setup described above, there was no propagation of detonation in 32 observations. From Figure 16 we can see that, based upon the 32 observations, upper limits of probability of propagation occurrence are 9 percent, 11 percent, and 15 percent for confidence levels of 90, 95, and 99 percent, respectively.

If we combine all the successful observations for 0.1 m (4 in.) separation and less, and for depth of explosive 38 mm (1-1/2 in.) and more for all lengths and widths of conveyors, we have a total of 67 observations without any detonation propagation. This corresponds to upper probabilities of propagation of 4.4 percent, 5.4 percent, and 7.6 percent for 90, 95, and 99 percent confidence limits, respectively.

SECTION 4

CONCLUSIONS

Conclusions

The following conclusions can be made based on the test results:

1. Propagation of explosion along a conveyor depends on the depth and width of the explosive. The smaller the depth and width of the explosive, the lower the probability of the occurrence of propagation of explosion.

2. A 38 mm (1-1/2 in.) depth of explosive on a 0.38 m (15 in.) wide commercially available corrugated rubber belt conveyor, as used in these tests, or a 0.1 m (4 in.) air-gap between explosives in two adjoining batches of explosive will prevent propagation of explosion along the conveyor.

Table 1 Critical depth tests of Composition B (Series 1)

Test No.	Conveyor[b] Type	Length m (ft.)	Width m (in.)	Depth of Explosive mm (in.)	Booster[f] Height mm (in.)	Thickness mm (in.)	Length m (in.)	Approx. Weight kg (lbs.)	Test Results
1	Rubber[a]	1.52 (5)	0.44 (17.5)	38[c] (1.50)	38 (1.50)	25 (1.0)	0.44 (17.50)	0.45 (1.00)	H.O.D. total length[g]
2	Rubber	1.52 (5)	0.44 (17.5)	38 (1.50)	38 (1.50)	25 (1.0)	0.21 (8.50)	0.23 (0.50)	H.O.D. total length
3	Rubber	3.05 (10)	0.44 (17.5)	38 (1.50)	38 (1.50)	25 (1.0)	0.44 (17.50)	0.45 (1.00)	H.O.D. total length
4	Rubber	3.05 (10)	0.44 (17.5)	25[d] (1.00)	38 (1.50)	25 (1.0)	0.44 (17.50)	0.45 (1.00)	H.O.D. 1.83 m (6 ft.) length
5	Rubber	1.52 (5)	0.44 (17.5)	25 (1.00)	25 (1.00)	25 (1.0)	0.44 (17.50)	0.34 (0.75)	H.O.D. total length
6	Rubber	3.05 (10)	0.44 (17.5)	25 (1.00)	25 (1.00)	25 (1.0)	0.44 (17.50)	0.34 (0.75)	H.O.D. 1.22 m (4 ft.) length
7	Rubber	2.44 (8)	0.44 (17.5)	32 (1.25)	32 (1.25)	25 (1.0)	0.44 (17.50)	0.41 (0.90)	H.O.D. 0.91 m (3 ft.) length
8	Wood	4.88 (16)	0.29 (11.25)	32 (1.25)	32 (1.25)	25 (1.0)	0.29 (11.25)	0.23 (0.50)	H.O.D. 0.46 m (1-1/2 ft.) length
9	Wood	4.88 (16)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.41 (0.90)	H.O.D. 0.46 m (1-1/2 ft.) length
10	Wood	4.88 (16)	0.43 (17.125)	38 (1.50)	38 (1.50)	25 (1.0)	0.43 (17.125)	0.45 (1.00)	H.O.D. 3.05 m (10 ft.) length
11	Wood	4.88 (16)	0.43 (17.125)	38 (1.50)	38 (1.50)	25 (1.0)	0.43 (17.125)	0.45 (1.00)	H.O.D. 3.05 m (10 ft.) length.
12	Wood	4.88 (16)	0.43 (17.125)	51[e] (2.00)	51 (2.00)	25 (1.0)	0.43 (17.125)	0.91 (2.00)	H.O.D. total length

Table 1 (continued) Critical depth tests of Composition B (Series 1)

Test No.	Conveyor[b] Type	Length m (ft.)	Width m (in.)	Depth of Explosive mm (in.)	Booster[f] Height mm (in.)	Thickness mm (in.)	Length m (in.)	Approx. Weight kg (lbs.)	Test Results
13	Wood	4.88 (16)	0.43 (17.125)	44 (1.75)	51 (2.00)	25 (1.0)	0.43 (17.125)	0.91 (2.00)	H.O.D. total length
14	Wood	4.88 (16)	0.43 (17.125)	38 (1.50)	51 (2.00)	25 (1.0)	0.43 (17.125)	0.91 (2.00)	H.O.D. total length
15	Wood	4.88 (16)	0.43 (17.125)	32 (1.25)	44 (1.75)	25 (1.0)	0.43 (17.125)	0.68 (1.50)	H.O.D. 0.61 m (2 ft.) length
16	Wood	4.88 (16)	0.29 (11.25)	51 (2.00)	51 (2.00)	25 (1.0)	0.29 (11.25)	0.68 (1.50)	H.O.D. total length

a. Commercially available rubber belt

b. Aluminum enclosure for conveyor used was 1.14 m (3'-9") W x 1.07 m (3'-6") H

c. Approximately 25 kg (55 lbs.) of Composition B

d. Approximately 31.8 kg (70 lbs.) of Composition B

e. Approximately 81.7 kg (180 lbs.) of Composition B

f. Composition C4 explosive (M112 demolition charge)

g. H.O.D. - High Order Detonation

Table 2 Critical depth tests of Composition B flake (Series 2)

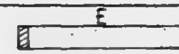
Test No.	Conveyor[a] Length m (ft.)	Conveyor[a] Width m (in.)	Depth of Explosive mm (in.)	Booster[b] Height mm (in.)	Booster[b] Thickness mm (in.)	Booster[b] Length m (in.)	Booster[b] Approx. Weight kg (lbs.)	Test Arrangement Configuration	Test Arrangement Expl. (E) m (in.)	Test Arrangement Space (S) m (in.)	Test Results
17	2.44 (8)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.45 (1.0)		2.41 (95)	(c)	Partial detonation. Comp. B scattered.
18	2.44 (8)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.45 (1.0)		0.2 (8)	(e)	Partial detonation. Comp B scattered
19	2.44 (8)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.45 (1.0)	Same as 17	2.41 (95)	-	H.O.D. Crater under the explosion
20	4.88 (16)	0.29 (11.25)	51 (2.00)	51 (2.00)	25 (1.0)	0.29 (11.25)	0.60 (1.33)	Same as 18	0.3 (12)	(f)	H.O.D. Crater under the explosion
21	4.88 (16)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.45 (1.0)	Same as 18	0.20 (8)	(g)	Partial detonation. Crater under the explosion. Comp. B scattered
22	4.88 (16)	0.29 (11.25)	38 (1.50)	38 (1.50)	25 (1.0)	0.29 (11.25)	0.45 (1.0)	Same as 18	0.15 (6)	(h)	H.O.D. Crater under the explosion
23	3.66 (12)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.43 (17)	0.91 (2.0)		1.52 (60)	0.61 (24)	Crater at donor side only N.P.[d]
24	3.66 (12)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.43 (17)	0.91 (2.0)	Same as 23	1.52 (60)	0.61 (24)	Crater at donor side only N.P.
25	3.66 (12)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.43 (17)	0.91 (2.0)	Same as 23	1.68 (66)	0.30 (12)	Crater at donor side only N.P.
26	5.49 (18)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.43 (17)	0.91 (2.0)		1.63 (64)	0.30 (12)	Crater at donor side only N.P.
27	5.49 (18)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.41 (16)	0.91 (2.0)	Same as 26	1.63 (64)	0.30 (12)	Crater at donor side only N.P.

Table 2 (continued) Critical depth tests of Composition flake (Series 2)

Test No.	Conveyor[a] Length m (ft.)	Conveyor[a] Width m (in.)	Depth of Explosive mm (in.)	Booster[b] Height mm (in.)	Booster[b] Thickness mm (in.)	Booster[b] Length m (in.)	Booster[b] Approx. Weight kg (lbs.)	Test Arrangement Configuration	Test Arrangement Expl. (E) m (in.)	Test Arrangement Space (S) m (in.)	Test Results
28	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.52 (60)	0.61 (24)	Crater at donor side only N.P.
29	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.68 (66)	0.30 (12)	Crater at donor side only N.P.
30	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.52 (60)	0.61 (24)	Crater at donor side only N.P.
31	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.68 (66)	0.30 (12)	Crater at donor side only N.P.
32	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.75 (69)	0.15 (6)	Crater at donor side only N.P.
33	3.66 (12)	0.43 (17)	70 (2.75)	70 (2.75)	25 (1.0)	0.43 (17)	1.27 (2.8)	Same as 23	1.78 (70)	0.08 (3)	Crater at donor side only N.P.
34	7.32 (24)	0.43 (17)	51 (2.00)	51 (2.00)	25 (1.0)	0.43 (17)	0.91 (2.0)		1.60 (63)	0.30 (12)	Crater at donor side only N.P.

a. Wooden conveyors with 0.61 m (2 ft.) W x 0.91 m (3 ft.) H x 2.44 m (8 ft.) L. aluminum enclosures.

b. Composition C4 demolition charge with J-3 blasting cap.

c. Explosive, Air Space, Booster, Spacer - cleats 76 mm (3 in.) H x 6.3 mm (1/4 in.) thick.

d. N.P. - No Propagation.

e. Explosive bed was subdivided by 11 cleats 0.20 m (8 in.) o.c.

f. Explosive bed was subdivided by 15 cleats 0.30 m (12 in.) o.c.

g. Explosive bed was subdivided by 23 cleats 0.20 m (8 in.) o.c.

h. Explosive bed was subdivided by 31 cleats 0.15 m (6 in.) o.c.

Table 3 Critical depth tests of Composition B flake (Series 3)

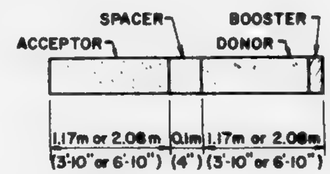
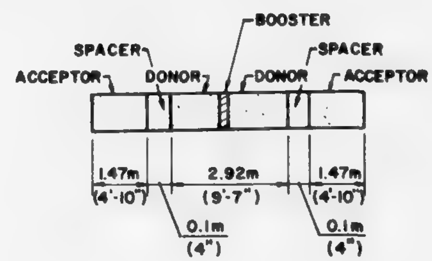
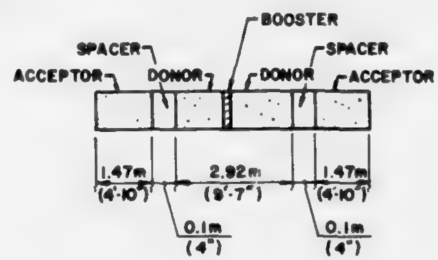
Test No.	Conveyor[b] Type	Conveyor[b] Length m (ft.)	Conveyor[b] Width m (in.)	Explosive Depth mm (in.)	Explosive Tot. Wt. kg (lbs.)	Spacer Type	Spacer Length m (in.)	Test Arrangement	Test Results
35	Wood[c]	2.44 (8)	0.29 (11.25)	38 (1.5)	22.7 (50)	Square			
36	Wood[c]	2.44 (8)	0.29 (11.25)	38 (1.5)	22.7 (50)	Round			
37	Wood	2.44 (8)	0.29 (11.25)	38 (1.5)	22.7 (50)	Square			
38	Wood	4.27 (14)	0.29 (11.25)	38 (1.5)	40.9 (90)	Round	0.1 (4)		Crater at donor side No propagation
39	Wood	4.27 (14)	0.29 (11.25)	38 (1.5)	40.9 (90)	Square			
40	Wood	4.27 (14)	0.29 (11.25)	38 (1.5)	40.9 (90)	Round[d]			
41	Wood	4.27 (14)	0.29 (11.25)	38 (1.5)	40.9 (90)	Square[d]			
42	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Round			
43	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
44	Rubber[a]	6.10 (20)	0.30 (12.00)	38 (1.5)	54.6 (120)	Square			
45	Rubber	6.10 (20)	0.30 (12.00)	38 (1.5)	54.6 (120)	Square[d]			Crater at donor side No propagation
46	Rubber	6.10 (20)	0.30 (12.00)	38 (1.5)	54.6 (120)	Round			
47	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			

Table 3 (continued) Critical depth tests of Composition B flake (Series 3)

Test No.	Conveyor[b] Type	Conveyor[b] Length m (ft.)	Conveyor[b] Width m (in.)	Explosive Depth mm (in.)	Explosive Tot. Wt. kg (lbs.)	Spacer Type	Spacer Length m (in.)	Test Arrangement	Test Results
48	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square	0.1 (4)		
49	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
50	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
51	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			Crater at donor side No propagation
52	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
53	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
54	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			
55	Wood	6.10 (20)	0.29 (11.25)	38 (1.5)	54.6 (120)	Square			

a. Commercially available rubber belt.

b. Aluminum enclosures for conveyors 0.61 m (2 ft.) W x 0.91 m (3 ft.) H.

c. Enclosures not used.

d. Composition B dust added on air gap covers to create a more hazardous condition.

Table 4 Critical depth tests of Composition B flake (Series 4)

Test No.	Conveyor[a] Length m (ft.)	Conveyor[a] Width m (in.)	Explosive Depth mm (in.)	Explosive Tot. Wt. kg (lbs.)	Booster Location	Test Results
1	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	
2	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	Conveyor damaged at booster - No propagation.
3	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	Center	
4	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	
5	2.44 (8)	0.43 (17)	51 (2.0)	27.3 (60)	End	H.O.D. Propagation[b].
6	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	
7	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	
8	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	End	
9	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
10	2.44 (8)	0.38 (15)	38 (1.5)	18.2 (40)	Center	
11	1.98 (6.5)	0.38 (15)	38 (1.5)	15.0 (33)	Center	
12	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	Conveyor damaged at booster - No propagation.
13	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
14	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
15	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
16	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
17	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
18	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
19	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	
20	1.83 (6)	0.38 (15)	38 (1.5)	13.6 (30)	Center	

a. Commercially available rubber belt with corrugations.

b. H.O.D. - High Order Detonation.

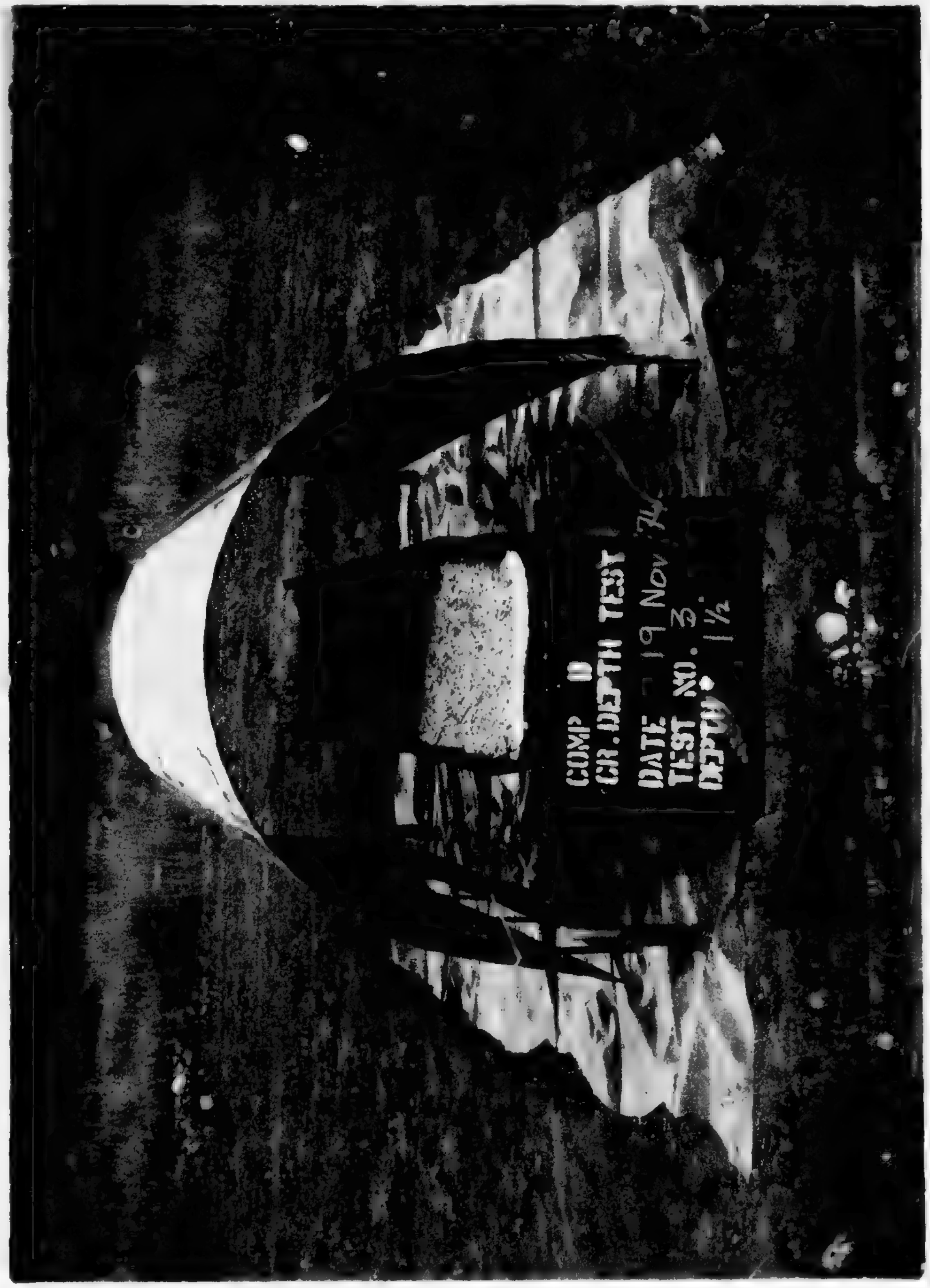


Fig 1 Simulated conveyor arrangement - Test Series No. 1

Fig 2 Simulated conveyor arrangement - Test Series No. 2

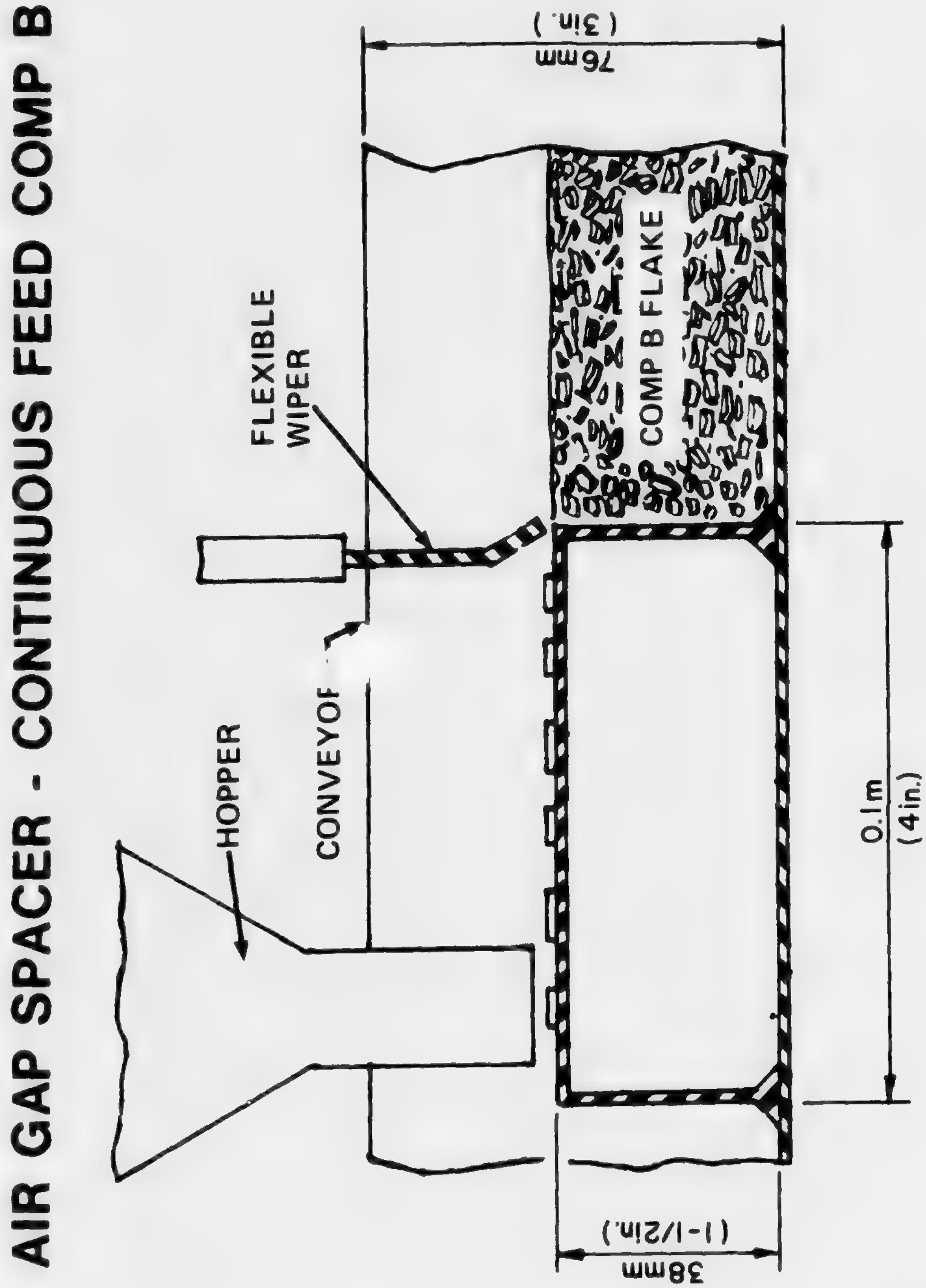


Fig 3 Schematic square air-gap spacer

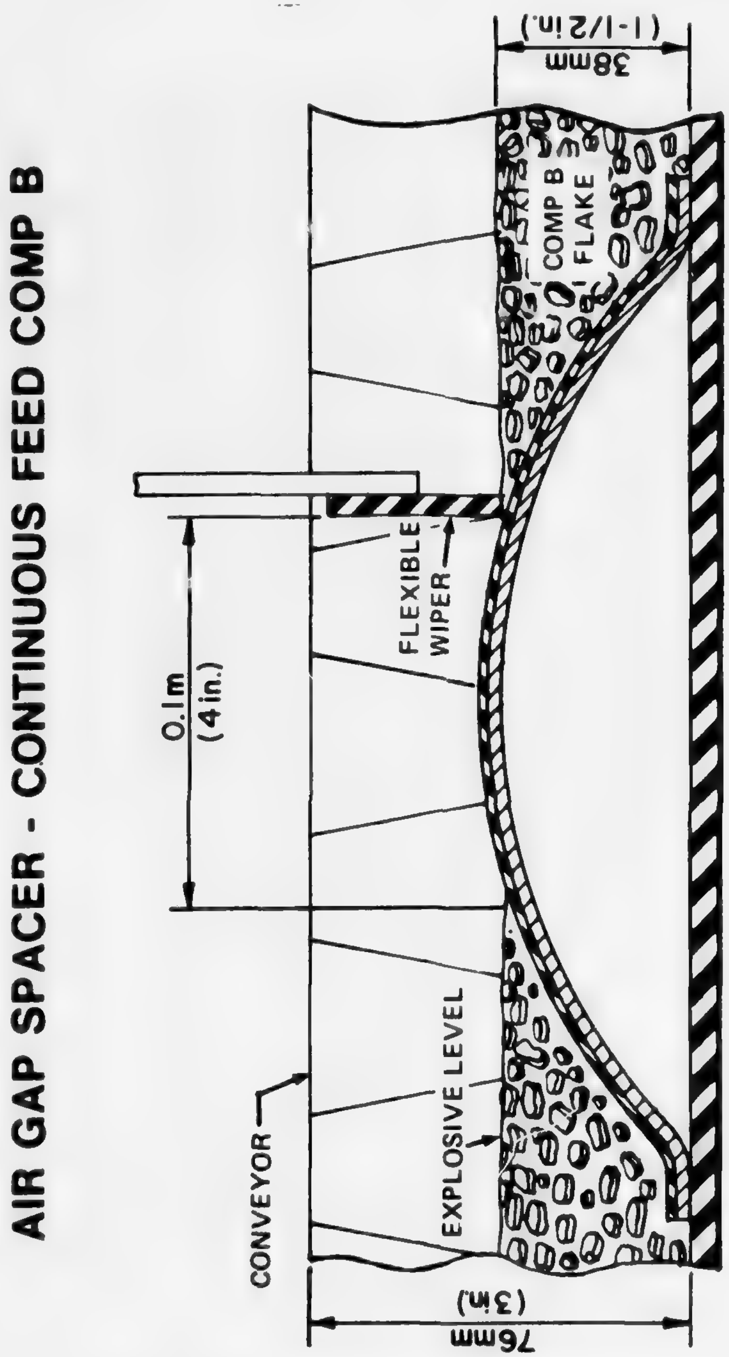


Fig 4   Schematic round air-gap spacer

Fig 5 Test setup using square spacer

Fig 6   Test setup using round spacer

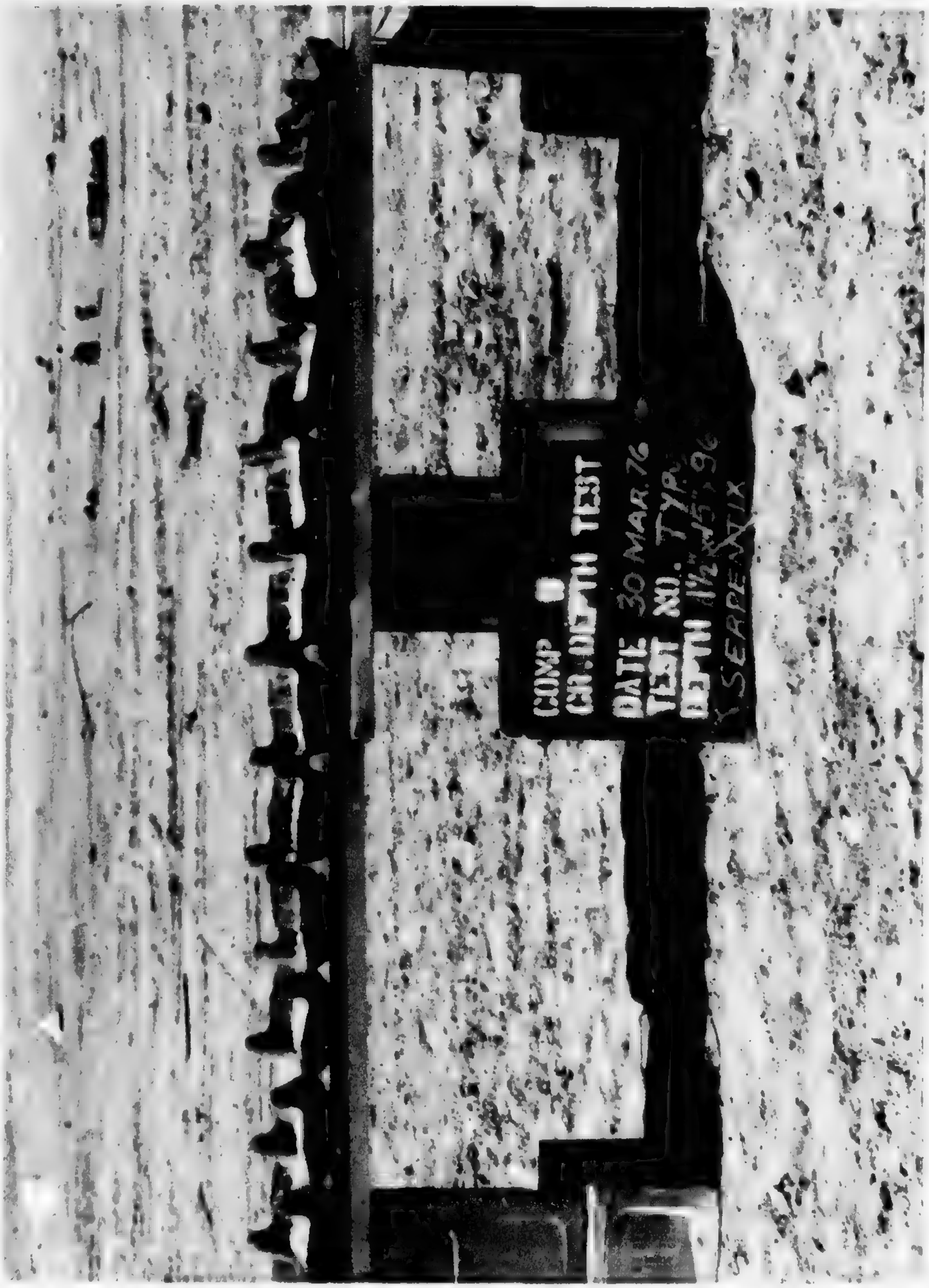


Fig 7 Longitudinal view of corrugated conveyor

Fig 8 End view of corrugated conveyor

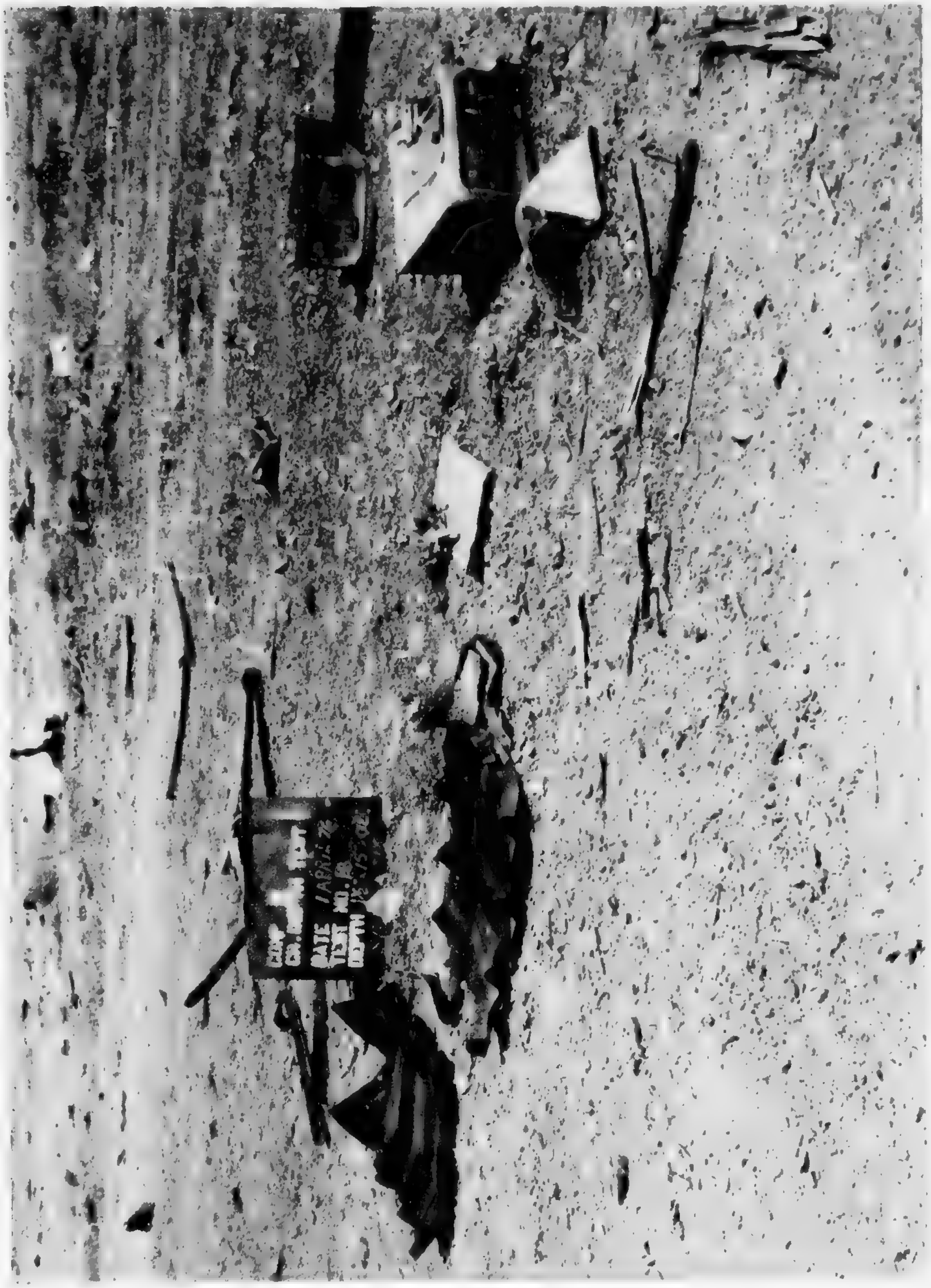


Fig 9   Typical post-shot view of corrugated conveyor tests

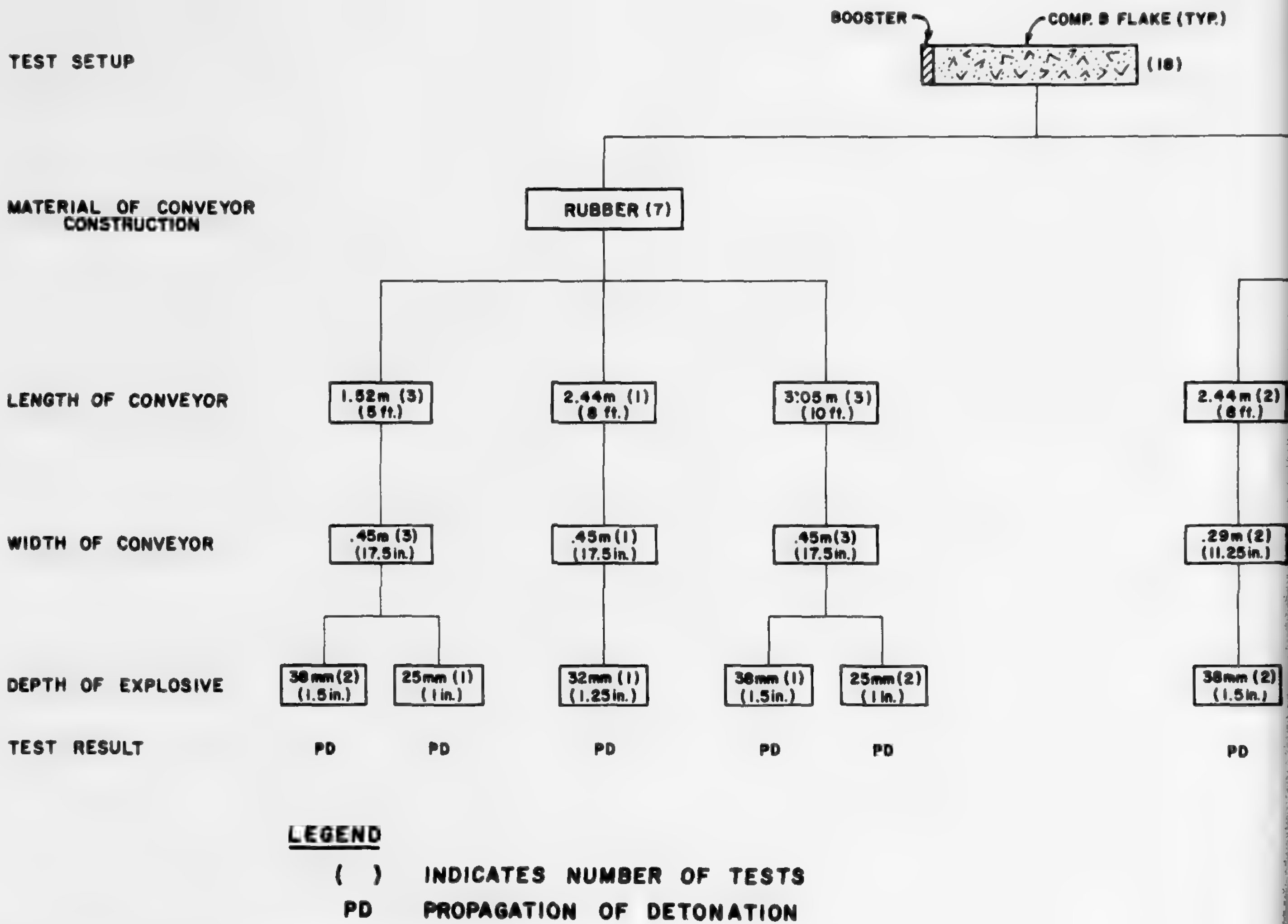
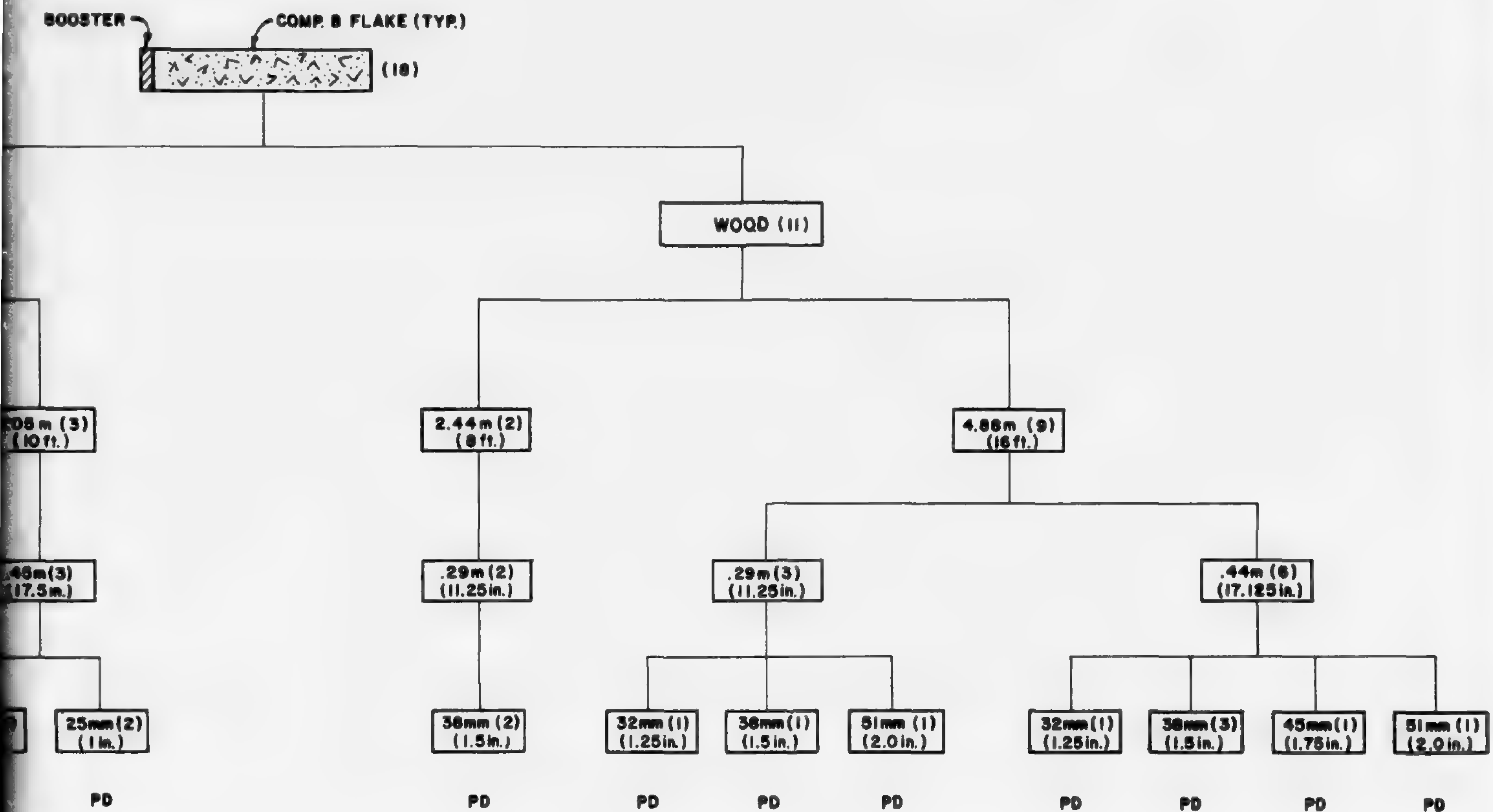


Fig 10 Details of Conveyor Tests with Booster at One End



BOOSTER
COMP. B FLAKE (TYP.)
(18)
WOOD (11)
08 m (3) (10 ft.)
2.44 m (2) (8 ft.)
4.88m (9) (16 ft.)
.46m(3) (17.5 in.)
.29m (2) (11.25 in.)
.29m (3) (11.25 in.)
.44m (6) (17.125 in.)
25mm (2) (1 in.)
38mm (2) (1.5 in.)
32mm (1) (1.25 in.)
38mm (1) (1.5 in.)
51mm (1) (2.0 in.)
32mm (1) (1.25 in.)
38mm (3) (1.5 in.)
45mm (1) (1.75 in.)
51mm (1) (2.0 in.)
PD
PD
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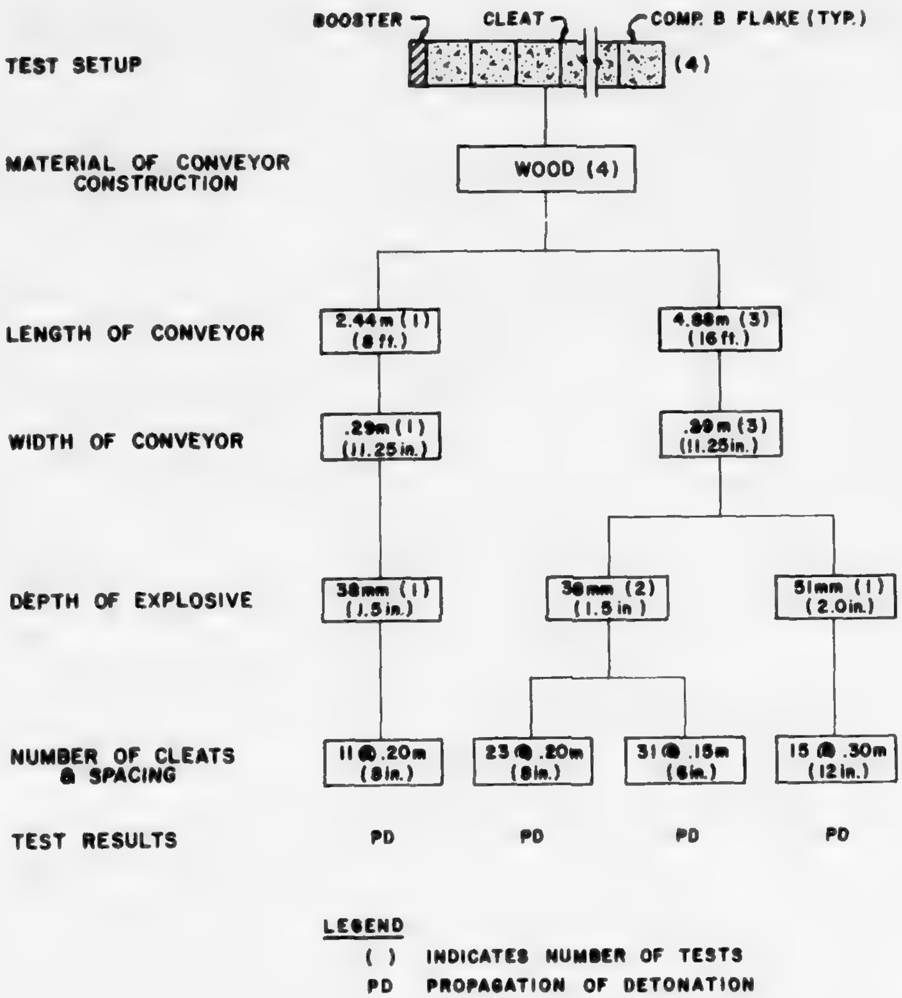

Fig 11 Details of conveyor tests with intermediate cleats

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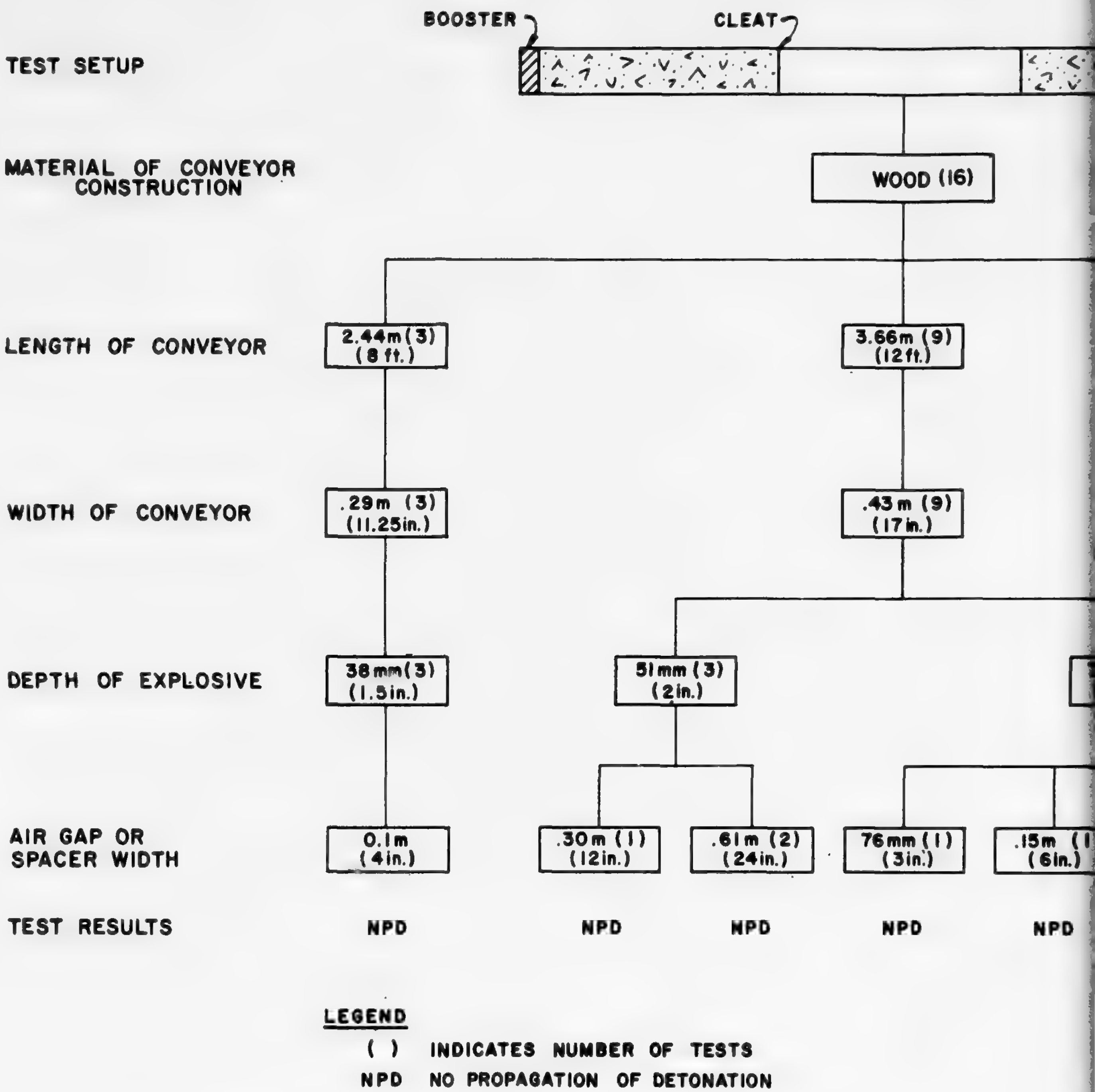

Fig 12 Details of Conveyor Tests with Donor and Acceptor Separated by Air-Gap

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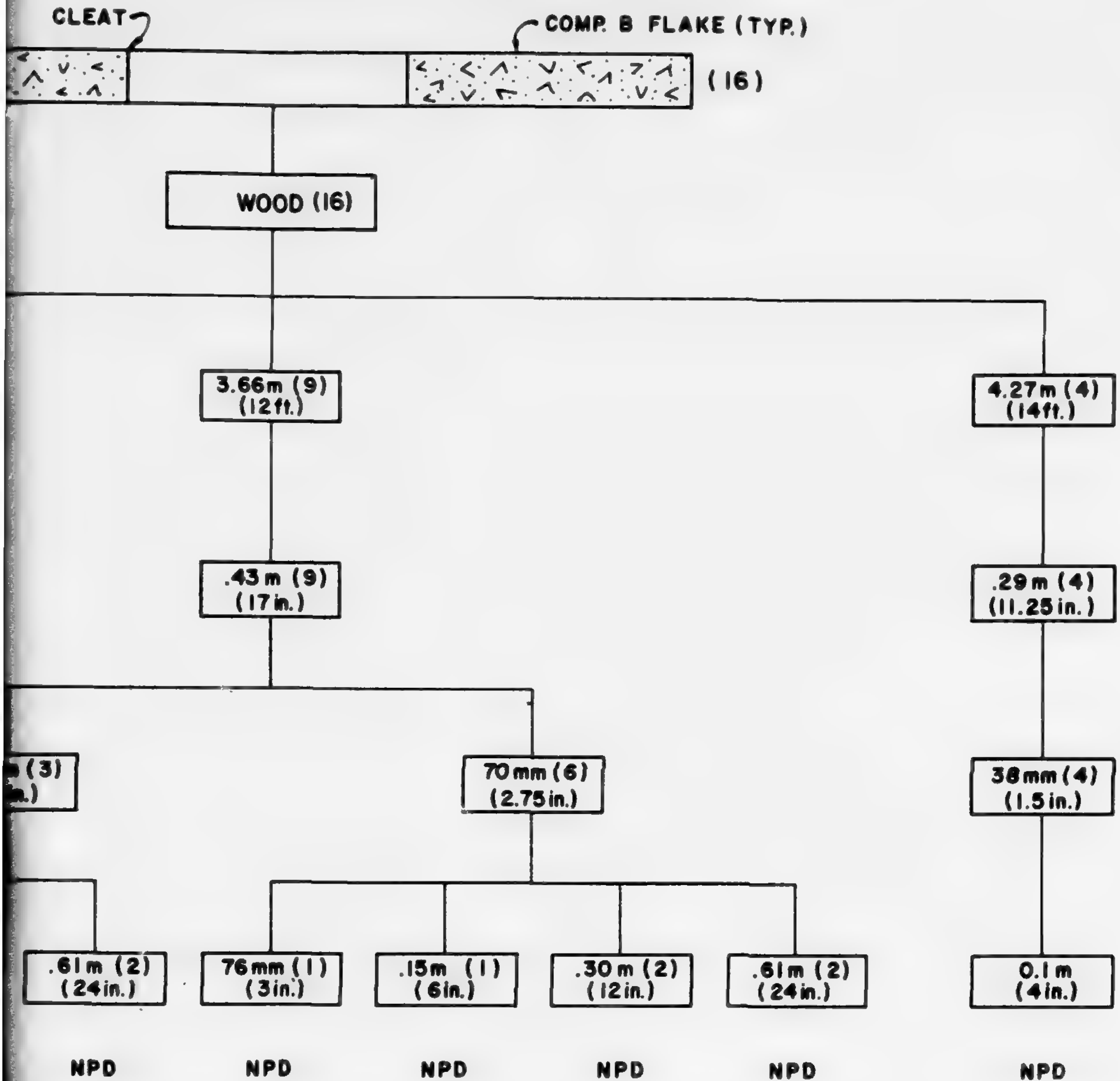

TESTS
TONATION

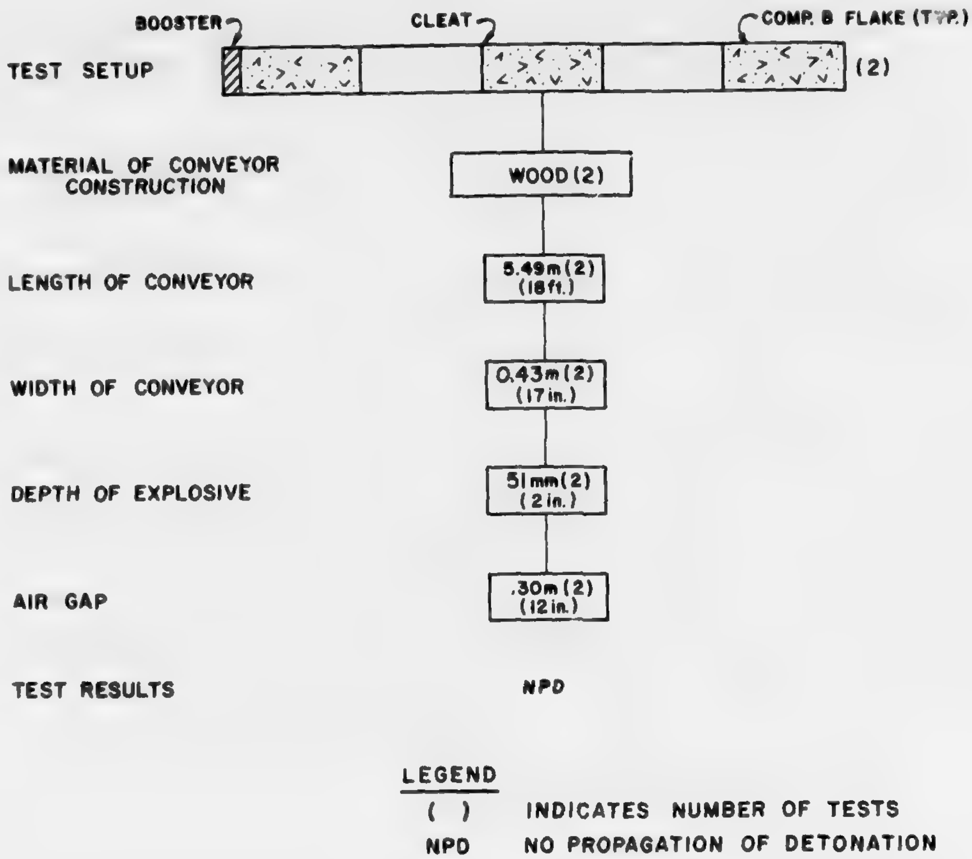

Fig 13 Details of conveyor tests with two air-gaps

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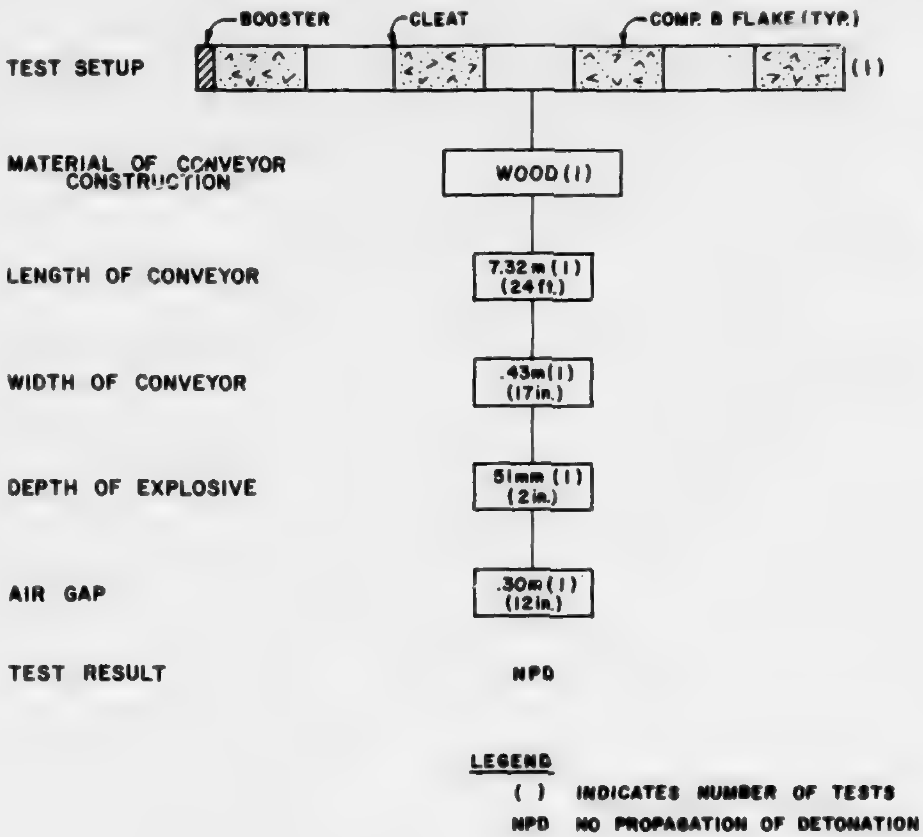


Fig 14 Details of conveyor test with three air-gaps

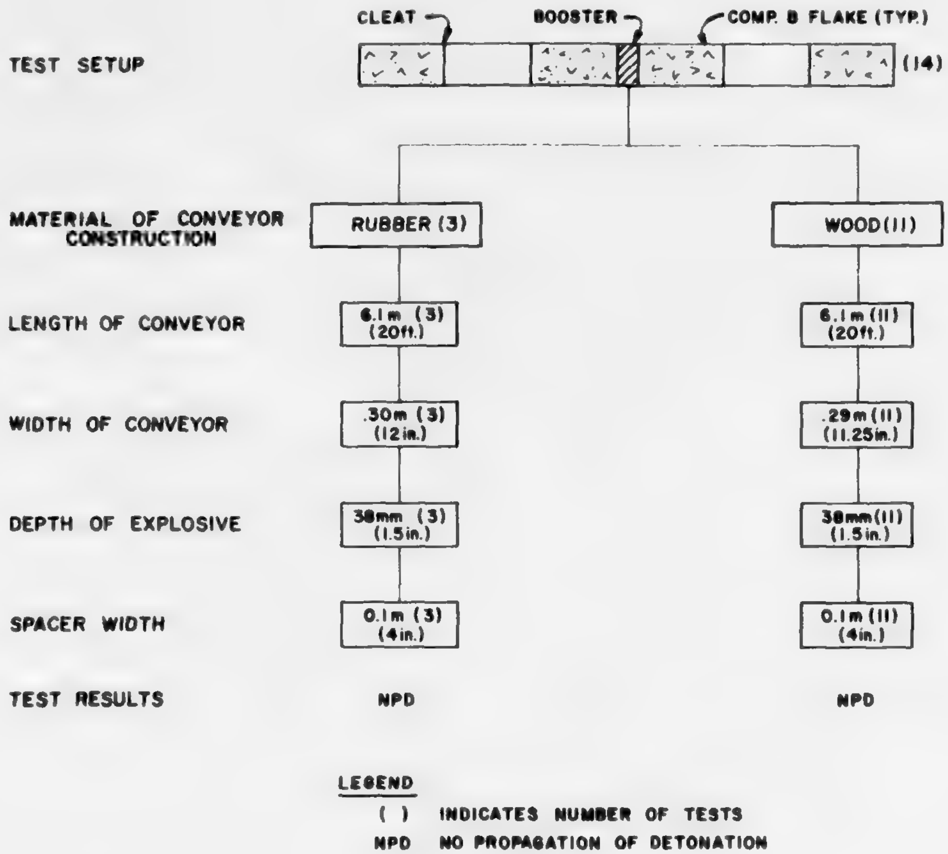


Fig 15 Details of conveyor tests with donor in the middle

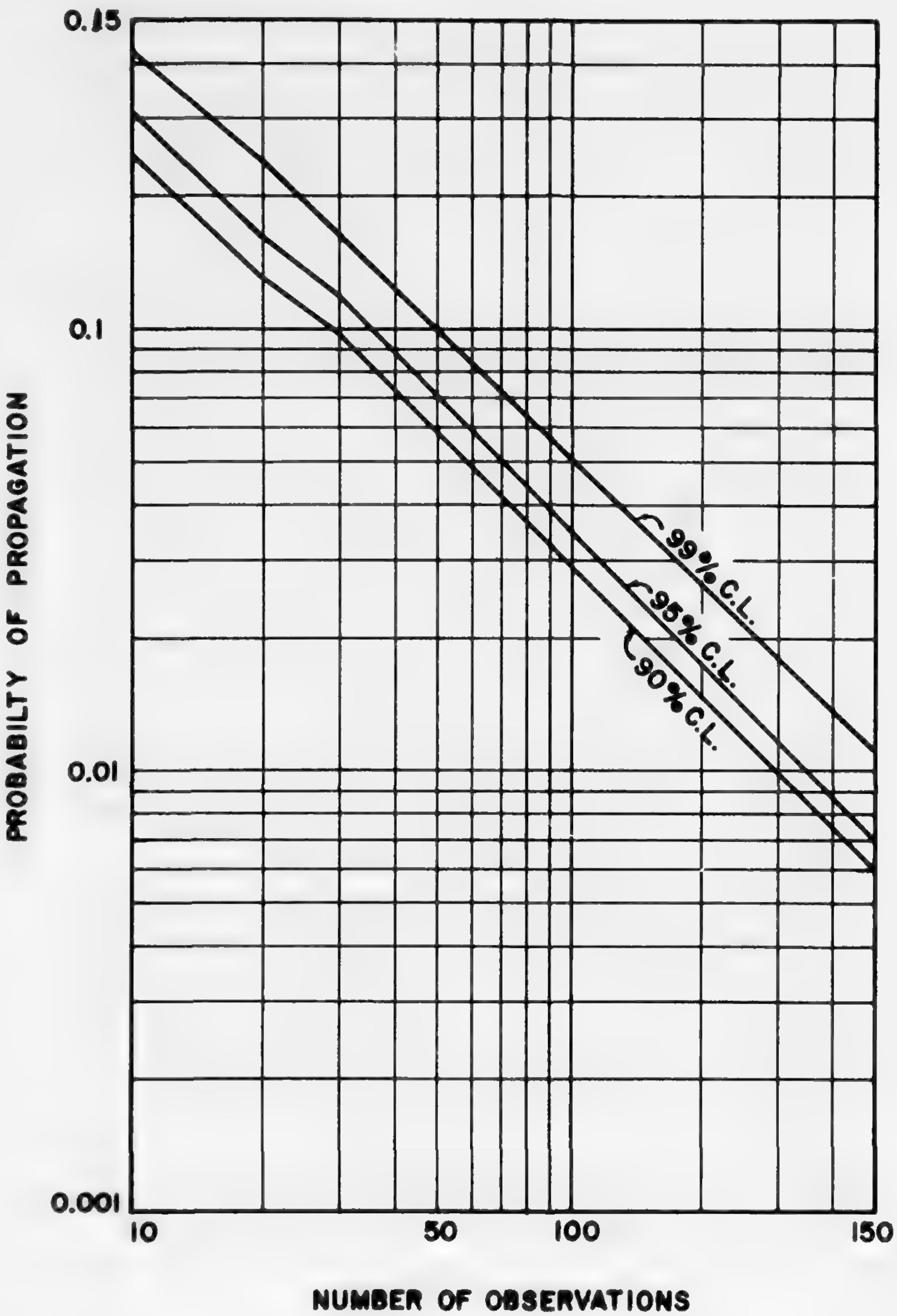


Fig 16 Upper limits of probability of propagation against number of observations for different confidence limits based on no observed propagation (p=0.0)

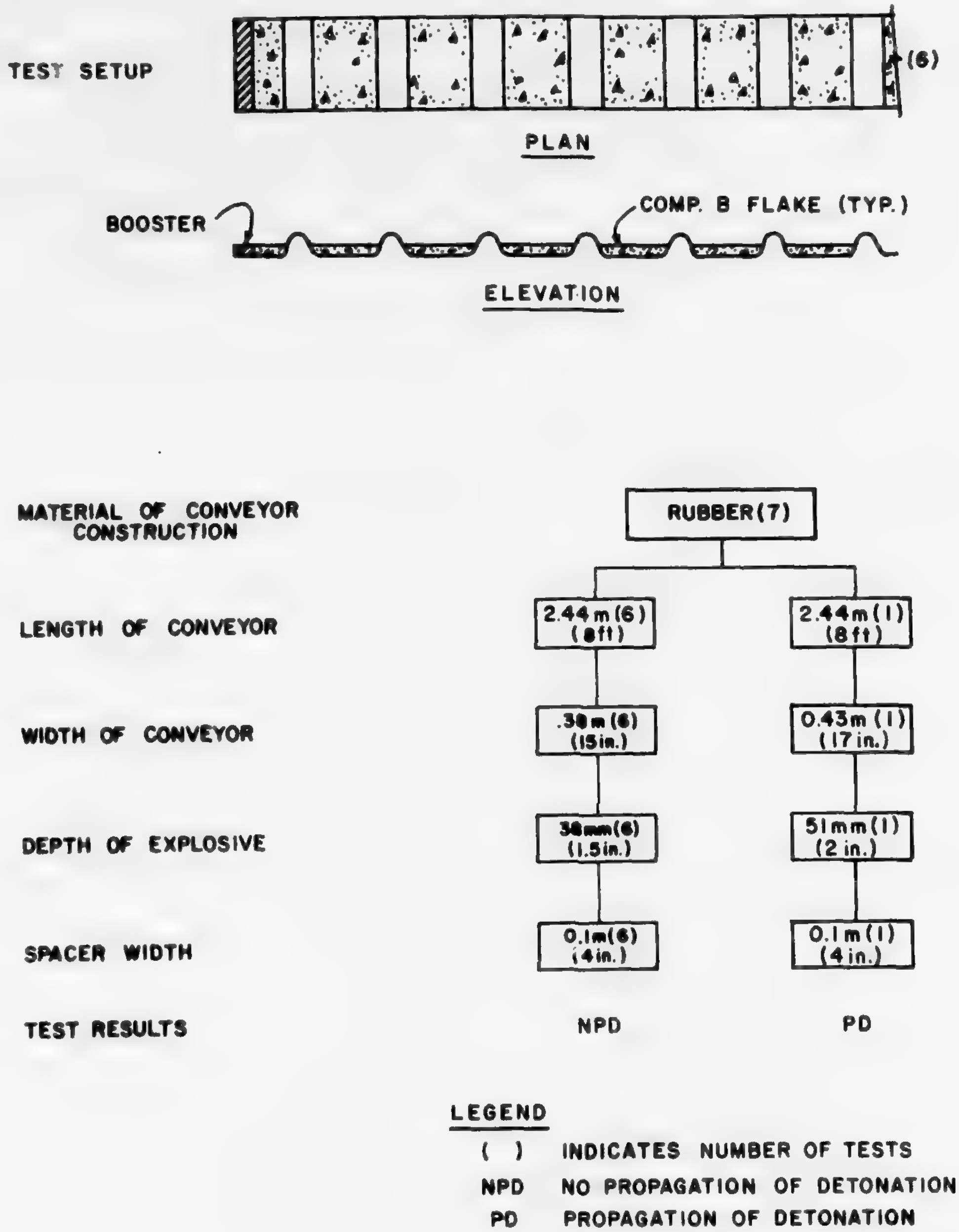


Fig 17 Details of corrugated conveyor tests with booster at one end

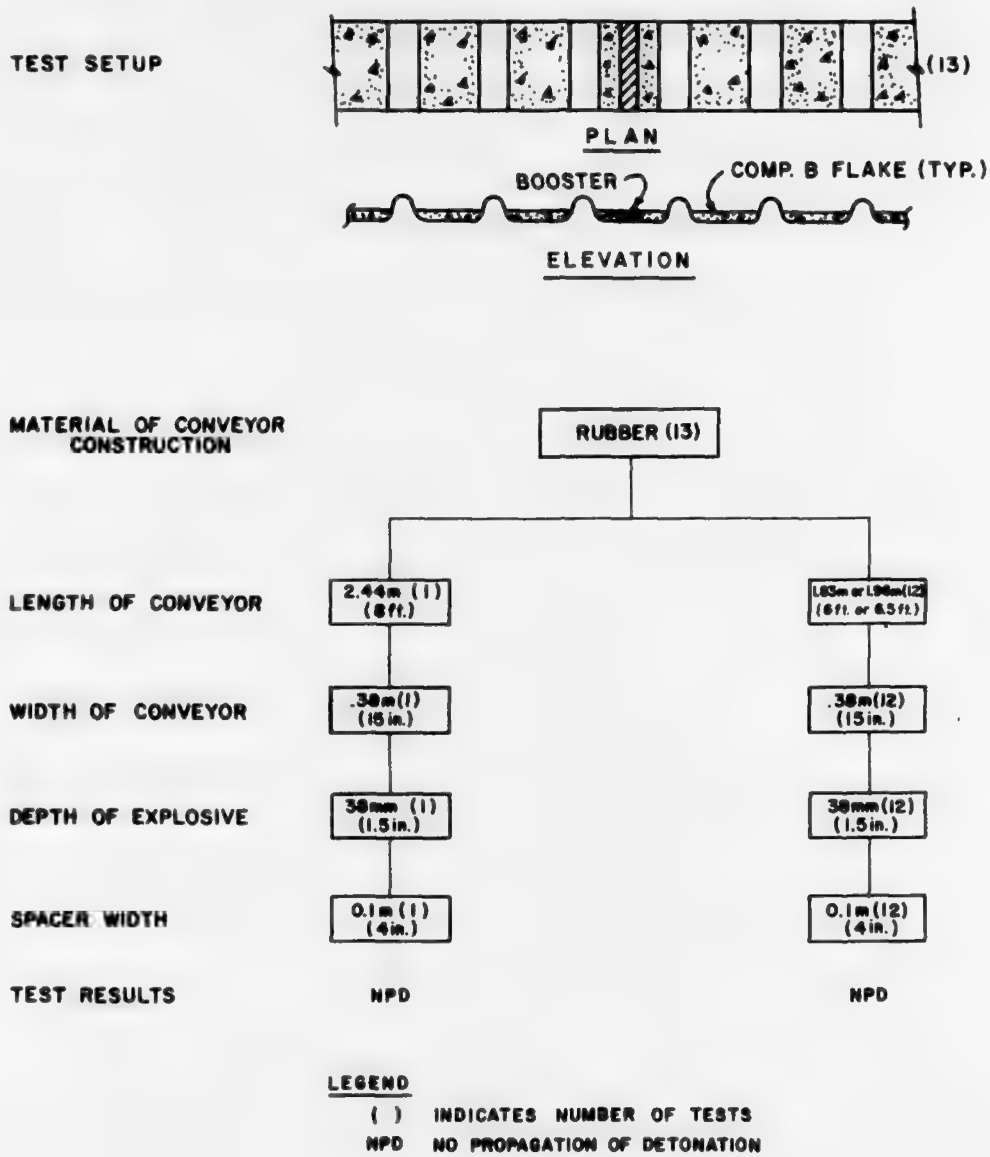


Fig 18 Details of corrugated conveyor tests with donor in the middle

APPENDIX A

PRELIMINARY BURNING AND PROPAGATION OF DETONATION TESTS OF TNT, COMPOSITION B, TRITONAL AND H-6 BY THE NAVY

In the beginning of 1972, the Navy was concerned about possible problems associated with the conveyor transportation of flake explosives. It was unknown what would happen to a bed of flake explosive if either burning or detonation was to occur at one point on the bed. The relationships between the depth of explosive, and the burning and detonation characteristics were not evident. Means were required to prevent propagation of explosion from one end to the other on a covered conveyor.

A test program, consisting initially of 9 tests (Ref. A.1) was started. In the first two tests, TNT Flake was placed in a paper container and ignited using an electric detonator. In tests 3 and 4, TNT was placed on plywood with depths of 25 mm (1 in.) and 50 mm (2 in.) respectively, and detonated using an electric detonator. In test 5, two patches of TNT were separated by 2.1 m (7 ft.) and one of them was initiated as before. In the remaining four tests efforts were made to start burning in a patch of loosely distributed TNT Flake by (1) placing two electric matches in the center of the explosive, (2) covering the electric match by Composition C-3 to serve as tinder, (3) bringing a pryogen (open flame producing) squib in contact with the TNT, and (4) embedding the pyrogen squib into the TNT Flake.

The conclusions drawn from the results of these tests can be summarized as follows:

(1) It may not be possible to detonate a one-inch bed of TNT, but it is more likely that a 2-inch bed would sustain a detonating reaction.

(2) Propagation of detonation between two batches of TNT Flake spaced 2.1 m (7 ft.) apart is very unlikely.

(3) It seems more difficult to cause burning of TNT Flake than it is to cause it to detonate.

Based on the results of the above tests, eight tests (Ref. A.2) using simulated conveyors fabricated from plywood were performed. Each conveyor was 0.43 m (17 in.) wide and 2.44 m (8 ft.) long and was subdivided into three compartments by means of plywood planks. Two of these compartments were 0.91 m (3 ft.) long while the third was 0.61 m (2 ft.) long. The depth of explosive

in all compartments was either 25 mm (1 in.), or 38 mm (1.5 in.), or 51 mm (2 in.) in any given test. Explosives used for the testing were TNT, Composition B, Tritonal (aluminum powder distributed evenly over Composition B), and H-6 (aluminum powder plus D-2 wax distributed evenly over Composition B). In each test the explosive was initiated using a booster with an E-99 electric blasting cap.

The test arrangements and results of these eight tests are summarized in Table A-1. Conclusions based on the test results are as follows:

(1) Composition B Flake does not detonate as readily as TNT Flake, probably due to its larger flake size.

(2) Compared to TNT, Composition B produces intense fire with practically no smoke.

(3) It is much easier to produce a fire in H-6 than it is in Tritonal.

(4) Aluminum makes it easier to start a burning reaction in either Composition B or TNT.

Effect of a conveyor cover on propagation of explosion was investigated in another set of seven tests (Ref. A.3). Width of the aluminum cover considered was 0.61 m (2 ft.), whereas its height was varied from 0.1 m (4 in.) to 0.3 m (12 in.). Five of the seven tests used either Tritonal or H-6, while the remaining two tests used intimate mixtures of ingredients used in the making of Tritonal and H-6. In each test the depth of the explosive was 25 mm (1 in.). Of the five covered conveyor tests performed, four tests had two batches of explosives separated by 0.9 m (3 ft.), and the last test had a separation of 3.35 m (11 ft.) between the donor and acceptor charges.

Table A-2 provides the details of the covered conveyor tests, the sizes, weights, and make-up of the explosive charges used in these tests.

The test results revealed the following:

(1) With a very low conveyor cover, the Tritonal or H-6 mixtures of dry bulk ingredients are very likely to propagate fire across a gap of 0.9 m (3 ft.) very easily.

(2) Intimate mixing of aluminum and Composition B may alter the resulting material burning performance somewhat more than if aluminum and TNT are mixed thoroughly.

Reference A.4 provides information about three additional tests performed by the U. S. Navy to determine the depth at which the explosives could be safely carried by the conveyor. To prevent propagation of explosion along the conveyor in case the critical depth was exceeded, it was proposed to space the explosives in 15.24 m (50 ft.) batches with 15.24 m (50 ft.) clear spacing between two adjacent batches.

Details of three full-scale tests are shown in Figures A-1, A-2, and A-3. In Figures A-1 and A-2, the details of a tritonal detonation test and H-6 burn test, respectively, are shown. Figure A-3 shows tritonal detonation test using two parallel conveyors separated by a distance of 0.61 m (2 ft.) at their closest point and diverging on a two degree angle. In all three tests, the conveyors were inclined with the ground at an angle of 5-1/2 degrees.

Conclusions drawn from a very limited testing are as follows:

(1) TNT, with or without aluminum powder, most probably would not sustain a detonation if it were less than 51 mm (2 in.) in depth.

(2) Composition B, with or without D-2 wax and aluminum powder, would probably not sustain a detonation even at a depth of 51 mm (2 in.).

References

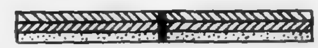
A.1 Plauson, Richard A., "Behavior of flake TNT, initiability, burning, and detonation" Memorandum for Code 4541 Files dated February 1972, Naval Weapons Center, China Lake, California. 93555.

A.2 Plauson, Richard A., "Behavior of Flake TNT, Flake Composition B, and Mixtures with Aluminum and Wax, Initiability, Burning and Detonation." Memorandum for Code 4541 Files dated 28 February 1972, Naval Weapons Center, China Lake, California. 93555

A.3 Plauson, Richard A., "Still More Explosive Burning Experiments: in Support of the McAlester Bombline Modernization Effort," Memorandum for Code 4541 Files dated 3 April 1972, Naval Weapons Center, China Lake, California. 93555.

A.4 Gill, J.O., and Groh, G.A., "Modernization of Bomb Filling Facilities (NAD McAlester)", Fourteenth Annual Explosives Safety Seminar, November 1972, Department of Defense Explosives Safety Board, Washington, D.C.

Table A-1 Initiability, burning, and detonation tests on different explosives

Test No.	Material	Depth of Explosive mm (in.)	Weight of Expl. on Conveyor Sect. 1 kg (lb.)	Sect. 2 kg (lb.)	Sect. 3 kg (lb.)	Test Setup[c]	Results
1	Comp. B	38 (1-1/2)	9.1 (20)	9.1 (20)	5.9 (13)		Local detonation No burning.
2	Comp. B	51 (2)	11.8 (26)	11.8 (26)	8.2 (18)		Local detonation No burning.
3[a]	Comp. B Aluminum Wax	51 (2)	- - -	16.4 (36) 2.3 (5) 0.7 (1.5)	8.2 (18) 2.3 (5) 0.5 (1)		Local detonation Burning reaction
4	Comp. B Aluminum Wax	38 (1-1/2)	9.1 (20) 2.3 (5) 0.7 (1.5)	9.1 (20) 2.3 (5) 0.7 (1.5)	5.9 (13) 1.8 (4) 0.4 (0.8)		Local detonation Burning reaction
5	TNT	25 (1)	6.4 (14)	6.4 (14)	4.1 (9)		Local detonation No burning.
6	TNT	38 (1-1/2)	9.6 (21)	9.6 (21)	6.4 (14)		Local detonation No burning.
7	TNT Aluminum	51 (2)	12.8 (28) 3.2 (7)	12.8 (28) 3.2 (7)	8.6 (19) 2.3 (5)		Total detonation.
8[b]	TNT Aluminum	25 (1)	6.4 (14) 1.6 (3.5)	6.4 (14) 1.6 (3.5)	4.1 (9) 1.1 (2.4)		Burning reaction.

a. Conveyor divided into two sections.

b. Test initiated in burning mode.

c. Shown in Elevation, Composition B, Wax, Aluminum, TNT

Table A-2 Covered conveyor burning tests for Tritonal and H-6

Test No.	Expl. Material	Separation Betw. Donor & Acceptor m (ft.)	Donor[a] Length m (ft.)	Donor[a] Weight Kg (lb.)	Acceptor[b] Length m (ft.)	Acceptor[b] Weight kg (lb.)	Height of Conveyor Cover[c] m (in.)	Results
1	TNT Aluminum	0.91 (3)	0.91 (3)	6.4 (14) 1.6 (3.5)	0.61 (2)	4.1 (9.0) 1.1 (2.4)	0.1 (4)	Propagation of fire. Intense burning. Melting of conveyor cover.
2	Comp. B Aluminum Wax	0.91 (3)	0.91 (3)	5.9 (13) 1.7 (3.7) 0.36 (0.8)	0.61 (2)	3.9 (8.5) 1.15 (2.5) 0.23 (0.5)	0.1 (4)	Propagation of fire. More intense burning. Melting of conveyor cover.
3	Comp. B Aluminum Wax	0.91 (3)	0.91 (3)	5.9 (13) 1.7 (3.7) 0.36 (0.8)	0.61 (2)	3.9 (8.5) 1.15 (2.5) 0.23 (0.5)	0.3 (12)	Propagation of fire. More intense burning. Melting of conveyor cover.
4	TNT Aluminum	0.91 (3)	0.91 (3)	6.4 (14) 1.6 (3.5)	0.61 (2)	4.1 (9.0) 1.1 (2.4)	0.3 (12)	Propagation of fire. Intense burning. Melting of conveyor cover.
5	Comp. B Aluminum Wax	3.35 (11)	0.91 (3)	5.9 (13) 1.7 (3.7) 0.36 (0.8)	0.61 (2)	3.9 (8.5) 1.15 (2.5) 0.23 (0.5)	0.1 (4)	Propagation of fire. Acceptor charge did not burn fully.

a. Width 0.43 m (17 in.), Thickness 25 mm (1 in.).

b. Width 0.43 m(17 in.), Thickness 25 mm (1 in.).

c. Made from 3 mm (1/8 in.) thick aluminum sheet. Width of cover 0.6 m (2 ft.).

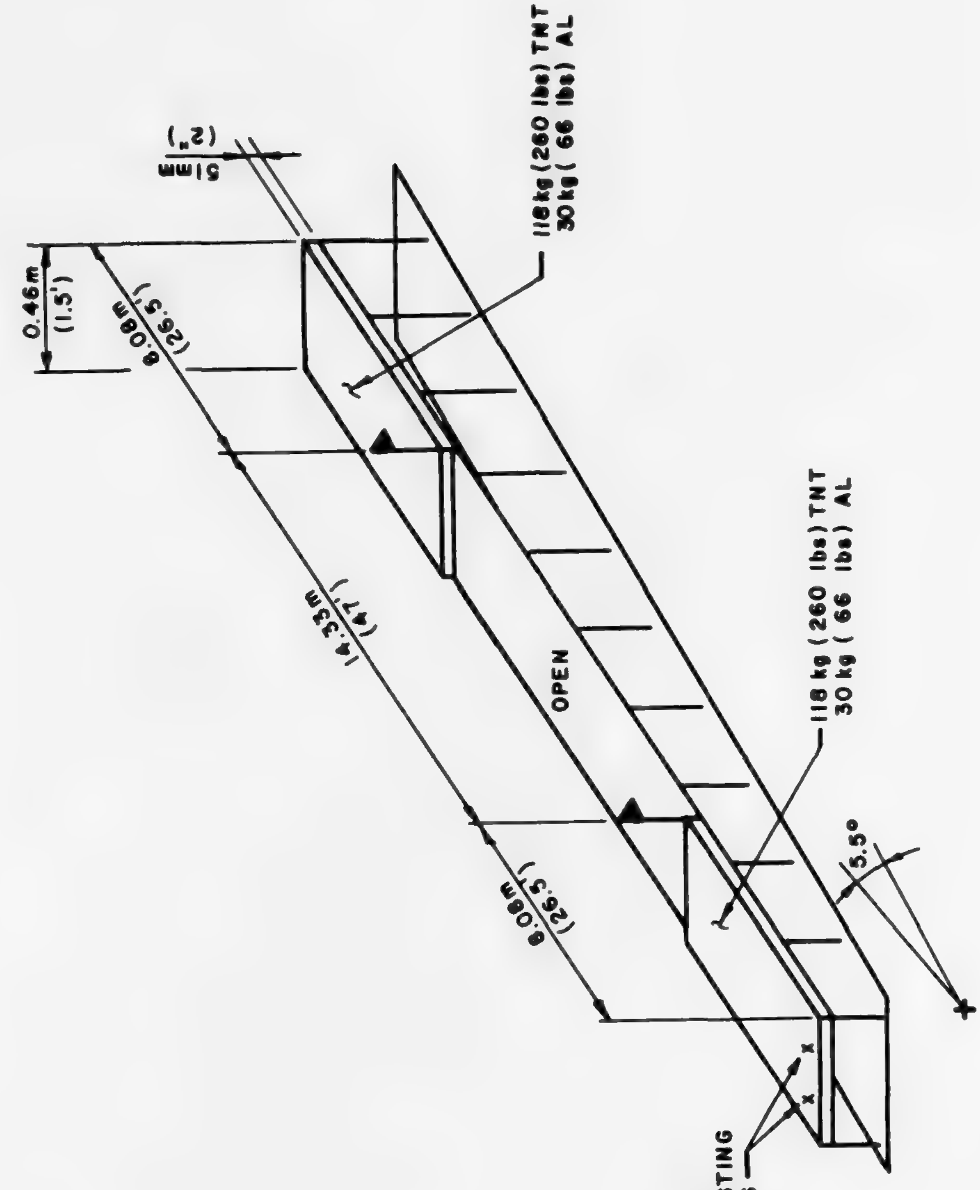


Fig A.1 Tritonal detonation test

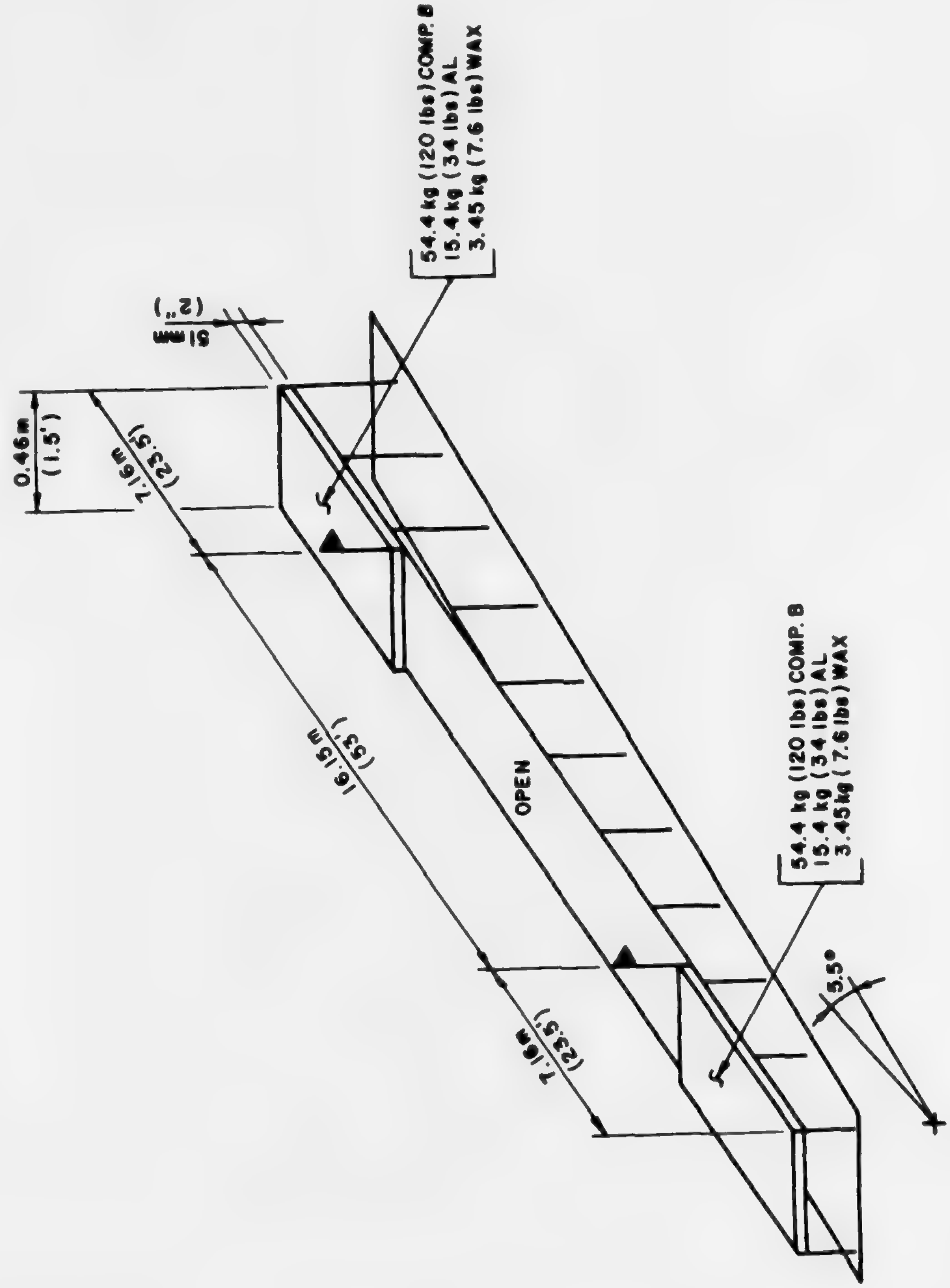


Fig A.2 H-6 burn test

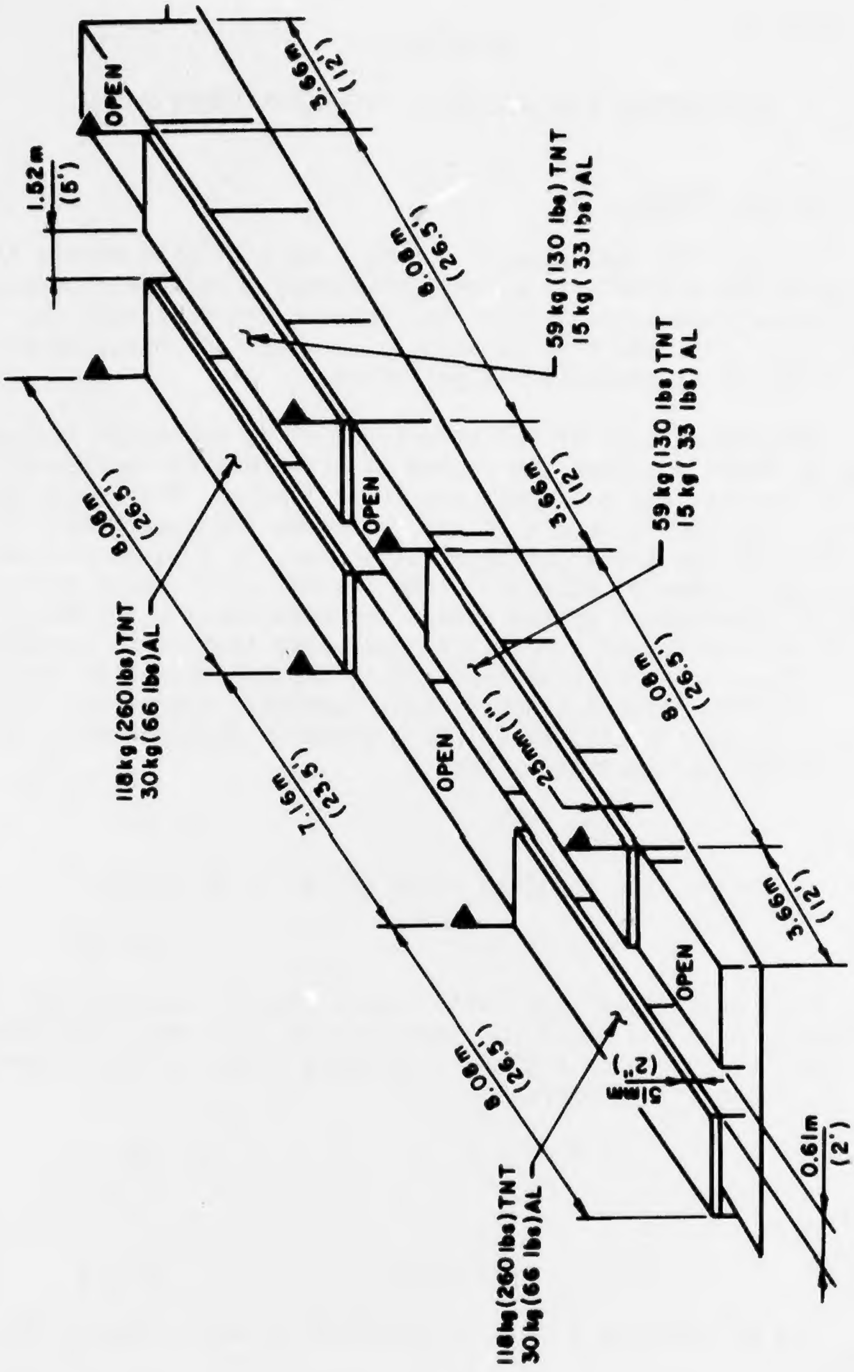


Fig A.3 Tritonal detonation test using two parallel conveyors

APPENDIX B

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

Statistical Theory

Attempt has been made in the main body of this report to evaluate the possibility of the occurrence of explosion propagation based upon a statistical analysis of the test results. This section of the report is devoted to mathematical means by which the statistical analysis was performed.

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero, whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by:

$$p = x/n \qquad \text{Eq. 1}$$

and, therefore, the expected value of (x) is given by:

$$E(x) = np \qquad \text{Eq. 2}$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as:

$$(1-p_2)^n = \varepsilon \qquad \text{Eq. 3}$$

where,

$$\varepsilon = \frac{1-\alpha}{2} \text{ and } \alpha<1.0 \qquad \text{Eq. 4}$$

Use of equation (3) is illustrated in the following example:

Example

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95 percent based upon 30 observations without a reaction occurrence.

Given

No. of Observations (n) = 30
Confidence level (α) = 95 percent

Solution

1. Substitute the given value of (α) into equation (4) and solve for ε;

$$\varepsilon = \frac{1-\alpha}{2} = \frac{1-0.95}{2} = 0.025$$

2. Substitute the given value of (n) and value of (ε) into equation (3) and solve for p_2

$$\varepsilon = 0.025 = (1-p_2)^{30}$$

or,

$$p_2 = 0.116 \text{ (11.6 percent)}$$

Conclusions

For a 95 percent confidence level and 30 observations, the true value of the probability of explosion propagation will fall between zero and 0.116; or statistically it can be interpreted that in 30 observations a maximum of 3.48 (=0.116 x 30) observations could result in a reaction for a 95 percent confidence level.

Probability Table

Table B-1 shows the probability limits and the range of the expected value E(x) for different numbers of observations. Three confidence limits, 90, 95, and 99 percent, are used to derive the probabilities.

Table B-1

Probabilities of Propagation for Various Confidence Limits

No. of Observations n	90 percent C.L. p_2	90 percent C.L. $E(x)$	95 percent C.L. p_2	95 percent C.L. $E(x)$	99 percent C.L. p_2	99 percent C.L. $E(x)$
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5